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EDUCATION IN A DEMOCRACY

SINCE the Select Committee on Estimates, in its eighth report for the session 1952–53, criticized the school building programme of the Ministry of Education, Political and Economic Planning, in two broadsheets entitled "Schools under Pressure" issued last December, has reviewed the position, first as regards the shortage of teachers, and second in relation to buildings and costs. These broadsheets have attempted to set out objectively the facts about developments in the provision of education in maintained and assisted schools in England and Wales, and to forecast future requirements as a proper basis for the discussion of educational policy. Little or no reference is made to the methods employed in education or to other important matters ; but that the comments in the broadsheets were ignored in the Civil Estimates debate in the House of Commons on April 27 reflects rather on the quality of the debate than on that of the broadsheets.

The first broadsheet is concerned with the pattern and size of the future school population, the problem of over-crowded classes, and the number of teachers required in the next few years both for maintaining present standards and for improving them. It is thus particularly relevant to the debate, which took place on a motion of Mr. R. Morley's pressing for a substantial reduction in the size of classes ; though the second broadsheet, dealing with the school-building programme and the cost of education, is no less relevant, in that Mr. Morley also asked for an enlarged school-building programme and additional expenditure on the educational services.

In the financial year 1953–54, the broadsheet puts the current cost of education, other than Government grants to the universities, at £363 million : a written answer in the House of Commons on March 15 gave the total as £392 million, an increase of £17 million on the Ministry of Education estimates. Allowing for the change in the value of money, Political and Economic Planning estimates that expenditure per schoolchild has increased between 25 and 35 per cent since 1938–39, the increase being most marked in the ancillary services, such as school meals and milk and the health services, and in scholarships. Over the same period, current expenditure on primary and secondary schools has increased by about 5 per cent per schoolchild. It is estimated also that the school population will continue to grow until 1959 and will then be 1,150,000, or twenty per cent greater than in 1950. After 1960, the school population will decline, but not to the level of 1950 ; in the mid-sixties it is likely to be about ten per cent higher than in 1950.

If present standards are maintained, the current cost of education at constant prices will rise by £35–£50 million in 1956–57 and £50–£70 million in 1959–60. To implement the Education Act of 1944 fully by 1960 and to reduce classes to the maximum sizes laid down by regulation would mean an extra current charge amounting to at least £120 million in that year. Moreover, during the next seven years, an additional capital cost of at least £50 million a

year will be required to keep pace with these increased numbers and maintain even present standards. Nor do these estimates provide for replacing old schools such as those which incurred the strictures of the Select Committee or for other improvements.

During the past two or three years, most education authorities have been more worried about finding accommodation for the extra children than about the supply of teachers. P E P considers that the recent increase in the rate of school building is changing this position and that, provided the building programme continues at its present level and is increasingly devoted to the needs of the secondary schools, sufficient new places should be available each year to accommodate almost all the extra children. From now on, the supply of teachers will be the most pressing problem until the numbers of children reaching the schools each year begin to level out.

In 1952 there were 222,000 full-time teachers in maintained and assisted schools, excluding special schools. To maintain 1950 standards, some 255,000 will be required by 1960, whereas at present annual rates of recruitment and wastage P E P estimates that only 245,000–250,000 are likely to be available, and in the late 1950's this shortage will be most pronounced among teachers of older children, and especially among graduate teachers. Moreover, in 1952 nearly three million children in maintained and assisted schools, or almost half the children in such schools, were being taught in over-crowded classes. To reduce classes to regulation level by the end of the decade would require an additional 20,000 teachers, while to implement the major provisions of the 1944 Act by the same date would bring the figure to nearly 100,000—a figure also given by Mr. N. C. Fisher, chief education officer for Manchester, to the Manchester Statistical Society.

Reasons could be advanced for regarding the estimates of Political and Economic Planning as too pessimistic. The net annual increase in the number of teachers is at present nearly 6,000. If this continues, the ratio of teachers to pupils in 1960 might be substantially better than now. Furthermore, there has been a great increase in the number of teachers who continue to teach after marriage. More teachers are remaining in the schools after reaching the retiring age, and the recruitment of non-graduates to training colleges has been remarkably successful.

These factors are indeed noted by P E P, but the dominant impression left by the broadsheets that far too much is being done extremely badly is probably correct; though its corollary that we should do less and do it well was ignored in the recent debate in the House of Commons. The educational enthusiasts of one party seem concerned only to experiment on the grand scale with theories no matter what may be lost in the process, and those of the other party to avoid taking unpopular decisions no matter how urgent they may be in the interests of the school-child. It was agreed on all sides that large classes of forty and fifty or more largely nullify the benefits of schooling, that they should be abolished and that this means more school building and more teachers. But no coherent policy emerged from either side, and there were few helpful suggestions. Mr. Morley advocated the spending of up to £100 million a year more on education, but gave no indication where the money is to come from apart from suggesting a reduction in defence expenditure; nor did he even consider other claimants such as the £1,000 million worth of work awaiting the Ministry of Transport against which only £50 million has yet been allotted. For the Government, Dr. K. Pickthorn, Parliamentary Secretary to the Ministry of Education, so far from giving any hint of a new or more vigorous policy, indicated that nothing more is contemplated than to wait for the bulge to pass. Affirming the Government's conviction that quality of education is what matters most, and that the size of classes is the chief of the calculable factors, he affirmed that, although there are now 500,000 more children than in 1950, the proportion in over-size primary classes is only slightly greater and the proportion of over-size secondary classes is less.

What this means in practice is made plain in the P E P broadsheet. If, in fact, the supply of teachers falls short of minimum requirements, between two and three million children born in the years immediately after the War will pass right through the schools without enjoying at any stage even the admittedly imperfect standards of 1950. On the evidence of these broadsheets and if, as Dr. Pickthorn's reply in the debate suggests, the claims of education are unlikely to be given a much higher place on the nation's list of priorities, there is little prospect of any considerable improvement for some years. Even a slight increase in the proportion of national resources going to education over and above that required to cater for the additional children would be in itself a valuable gesture in that it might help to maintain the morale of the teaching profession and hence stimulate recruitment.

Some appreciation of this was manifest in the debate, though in connexion with reducing the size of classes, there was little evidence that the need for great flexibility on the part of the education authorities and the organized teaching profession was realized. Moreover, as P E P points out, no convincing evidence has been adduced why the maximum size of a primary school class should in theory be thirty and of a secondary school class thirty. The desirable levels may well vary with both school and subject.

In these broadsheets, Political and Economic Planning makes several suggestions for supplementing the number of qualified full-time teachers, by drawing on other sources of supply and deploying the teaching force in the best possible way. For example, assistant or apprentice teachers might be used in infant schools, and many of these assistants could be recruited from the secondary modern schools. In the grammar schools, more children might be encouraged to take a full sixth-form course so as to increase the pool from which many qualified teachers are now drawn. Greater efforts could be made to encourage women teachers who have left the profession, usually on marriage, to return to it in a part-time capacity, and more older people from other professions might be encouraged to take up

teaching. It might also be advisable to extend the retirement age for certain classes of teachers under appropriate safeguards, and the reason why the profession loses annually as many as ten thousand teachers urgently needs investigating.

Since the shortage of graduate teachers is likely to be acute, graduate recruits are needed to teach a wider range of subjects than those in which they specialized at the university. To some extent this same end could be achieved by a modification of school curricula. Here we are concerned with fundamental questions of the content and purpose of school education, including preparation for a university, as has already been emphasized in relation to the teaching of science and mathematics.

Few of these suggestions attracted much attention in the House of Commons debate. Mr. M. Stewart, summarizing the arguments of the Opposition, recognized the desirability of more strenuous efforts to attract the part-time services of women teachers who had left the profession, and for a realistic attitude to the age of retirement. There was little appreciation, however, of the need for immediate action, and the arguments for higher status and salaries for teachers were unaccompanied by any evidence of a disposition to shed old prejudices, which Mr. Angus Maude urged in advancing the most constructive suggestion of the debate. This was on the lines of one made by P E P, and more specifically aims at securing more teachers from the secondary modern schools by a system of apprenticeship for selected girls who would ordinarily leave school at fifteen or sixteen.

Mr. Maude believes that there is a reasonable prospect of gathering in this way good material which would otherwise go into one of the numerous vocations and auxiliary professions now attracting young women who miss the high road to the training college. He suggests that one or two local education authorities should experiment with a system in which selected girls were encouraged to remain at school until eighteen, part-time as grammar school pupils and part-time as assistant teachers under the supervision of qualified teachers in primary schools. At the end of three years, they would go on to training colleges in the ordinary way.

This suggestion at least merits a trial on the scale Mr. Maude proposed, for it offers some immediate relief to staff shortages in the primary schools, quite apart from the reasonable prospect of a contribution to an ultimate increase in the number of trained teachers. One other suggestion for immediate relief which has been made recently, though it was not mentioned in the broadsheets, and in the debate was rejected by the only two speakers who referred to it, is to allow local authorities the option of raising the school entry age to six. Admittedly a palliative to offset the strain of retaining the extra year or two of school life at the upper and more valuable end, this proposal received no comment from Dr. Pickthorn, who failed to give the assurance requested by Mr. Stewart that no such step was contemplated by the Government.

That price, however, might well be worth paying to remove the handicap of classes of forty or more in the areas where the evil is most rife. The point is that, as P E P emphasizes in conclusion, the shortage of teachers is simply one aspect of the problem of the wise use of the nation's trained men and women. The greatest care is needed in planning the use of these very scarce resources, and no prejudices should hinder them from being used where they are most effective. Much greater willingness on the part of all concerned to accept changes is required than was manifest for the most part in the House of Commons debate. Flexibility of approach and not a doctrinaire attitude offers the best hope of meeting the urgent needs of education in Britain.

A MODERN VIEW OF EVOLUTION

The Major Features of Evolution

By Dr. George Gaylord Simpson. (No. 17 of the Columbia Biological Series.) Pp. xx+434. (New York: Columbia University Press; London: Oxford University Press, 1953.) 48s. net.

IT is a curious fact that the revelations of the general principles underlying the inorganic and the organic aspects of Nature have met with very different receptions after they were first enunciated. When Newton published his "Principia", it was immediately recognized that the reign of law and order in physical science had begun. In the biological field, on the other hand, it is nearly a century since Darwin put forward the theory of natural selection and Mendel demonstrated that inheritance is particulate; but only recently have men of science realized, chiefly from the work of Sir Ronald Fisher, that during all this time they have held the key to the problem of evolution in their hands. The Mendelian mechanism of genes which segregate, recombine, and occasionally mutate, provides exactly the raw material of variation required for evolution; and natural selection provides a mechanism for producing change, adaptation and states of a high degree of improbability. Darwin also recognized the importance of isolation, which, together with mutation, recombination and selection, are sufficient to explain the evolution of plants and animals.

Since evolution is a slow process, it is natural that palæontologists should have provided the major part of the evidence on the *course* which evolution has taken. In the past, unfortunately, they have been prone to draw conclusions regarding the *cause* of the results which they have found in their strata, and to support such views as Lamarckism, recapitulation and orthogenesis. It is now clear that nobody is competent to speak, write or think about evolution unless he is familiar with modern research not only in morphology and palæontology, but also in genetics (including population genetics), taxonomy and ecology. It is because Dr. George Gaylord Simpson has all this necessary equipment that his latest book, "The Major Features of Evolution", deserves the closest and widest attention.

Himself foremost as a palæontologist, he shows how erroneous was the reasoning on which Lamarckian, recapitulatory or orthogenetic views of evolution were based, and he provides one of the best demonstrations yet given to show that selection is a sufficient explanation of evolution. The *ne plus ultra* types of argument of hypertely or excessive adaptation, or of the supposed uselessness of characters

advanced by opponents of selection, go down like ninepins before his trenchant analysis. "The assumption is that in true hypertely, the extreme is inadaptive and did or will lead to extinction", to which Dr. Simpson prefaces the prophetic remark that "to a lemur, man must be strongly hypertelic", a conclusion in which the lemur would only be confirmed if he knew of the thermo-nuclear bomb (which had not yet been exploded when Dr. Simpson wrote). It must also be remembered that this development is a part of the struggle for existence and is introduced to confer survival value—a sad example of selection in its extreme form.

So thorough-going a selectionist is Dr. Simpson that he does not share Prof. D. M. S. Watson's view that the secular changes which he has observed in the reduction of cartilage-bones and flattening of the skull during the evolution of amphibia are inadaptive. It is now thought that cartilage in the skull is a cænogenetic adaptation phylogenetically more recent than bone; I published this suggestion in 1937, and A. S. Romer has independently been led to the same conclusion. Recognizing that retention of cartilage in the adult is a neotenous phenomenon, and that neoteny is a widespread adaptive feature in amphibian evolution, Dr. Simpson argues that the reduction of cartilage-bone is therefore an effect of selection.

If a science only acquires respectability when it is susceptible to experimental and mathematical treatment, then this quality can now certainly be claimed for evolution. Evolution now in progress is being studied experimentally by T. Dobschansky and by E. B. Ford. As for mathematical treatment, in addition to the radioactive time-clocks of the geologist, and to the measurements of the effects of different intensities of selection, there are now objective estimates of rates of evolution, of rates of mutation, and of the duration-times of genera and of species in different groups of animals. Many of these results are due to Dr. Simpson's own researches, and the analysis to which he subjects them is of the greatest interest. He finds that evolution-rate is not correlated with mutation-rate, nor with the degree of variability of the populations of evolving animals, nor with generation-lengths. A few years ago it would have appeared fantastic to claim to be able to make such generalizations as these; but advances in knowledge in genetics and palæontology have been such that Dr. Simpson is able to give concrete examples as evidence for all these statements. His conclusion (based on a suggestion made by A. H. Sturtevant), that mutation-rate itself is subject to selection, and that it is minimal in well-adapted populations, is in full agreement with E. B. Ford's view that the variability of a population is at its minimum under optimal conditions.

One of the most interesting of Dr. Simpson's discussions is concerned with lineages which have evolved at rates markedly more slow or more rapid than the majority of their related lineages. Cases of accelerated evolution have the additional interest that to them so frequently belong the origins of the higher taxonomic categories. Here Dr. Simpson rejects a view once held by W. D. Matthew that, in the early Tertiary days of the mammals, the orders were all there but not yet differentiated into their many families. Dr. Simpson shows that the award of rank to the higher categories is *ex post facto*, and that they must be regarded as rising from the ranks of species, by normal though accelerated promotion. The early Tertiary mammals were together worth nothing more than an order, and would be recognized as such if they had then gone extinct. It is only because the birds succeeded in mastering the air, and the mammals afterwards radiated so widely, that both these groups have earned promotion to the rank of class.

Another feature of interest in the origin of groups leading to higher categories is the fact that they are usually preceded by a marked gap in the fossil record. Many factors may be responsible for this; but I should like here to put in a plea for the hypothesis of 'clandestine evolution' which I put forward in 1930, and with which Dr. Simpson would doubtless agree since he allows that pædomorphosis may result in sudden and radical changes in adult structure, evolution having gone on in the juvenile state (probably not preserved in a fossil condition) which becomes the new adult when the old one is dropped off the end of the life-history.

There is no reason for supposing that such large changes result from 'saltations', or 'macromutations'; the ordinary processes of selection working on ordinary mutations and recombinations appears adequate to account for the production of any change. It follows that there is no basis for a distinction between so-called 'micro-evolution' and 'macro-evolution'.

So much light has been thrown on the mechanism of evolution that it is important to bear in mind the corners of the field which are still dark, and mutation is one of these, for its incidence and causation are unknown, a demonstrated ignorance which is the chief condemnation of Lamarckian views.

It is sometimes thought that the mutation-rates found in Nature, averaging 1 in 10^6 per locus, are too slow to bring about evolution. But Mendelian particulate inheritance does away with the need for high mutation-rates, for it conserves variance; and if mutation were more frequent, genes would be lost before recombination and selection had had time to derive from them what possible advantages they might possess. Mutation not only need not, but must not, be frequent. Even then, mutation-rate is high enough not to be a limiting factor in evolution, which means that it is not mutation but selection which immediately controls the direction which evolution takes.

It is to be hoped that the days are past when the effects of selection could be regarded as the result of 'blind chance'. Dr. Simpson shows that selection is the very reverse of a random or chance factor. Nor can it any longer be said that selection is only negative and creates nothing new. By selection of appropriate genes in the gene-complex, heritable change is produced and contributed directly to the variability. There is one verbal point here on which Dr. Simpson adopts a view which others may or may not follow. He regards Darwinian selection as solely differential mortality, and genetic selection (which he calls non-Darwinian) as differential reproduction resulting in heritable change in populations between one generation and the next.

It is possible that some of the army of Darwin's followers who stressed the tooth-and-claw struggle for existence may have spread the idea that selection was a purely destructive agent. Incidentally, such a view of selection is no longer tenable, for it is mostly a matter of allelomorphic genes, enzymes and ecological efficiency at the chemical and physical levels, without bloodshed or war. But Darwin himself never lost sight of the fact that differential reproduction is the

effective element in selection. For example, in the "Origin of Species", Chapter 3, he wrote: "Variations, however slight and from whatever cause proceeding, if they be in any degree profitable to the individuals of a species, in their infinitely complex relations to other organic beings and to their physical conditions of life, will tend to the preservation of such individuals, and will generally be inherited by the offspring".

Dr. Simpson envisages the possibility of a population in which all the individuals lived lives of the same length but some produced twice the number of offspring produced by the others. This he regards as non-Darwinian selection. But if the genetic make-up of these rapid reproducers conferred any advantage whatever, even if only that of number, such an event would be fully covered by Darwin's definition of selection quoted above. Furthermore, Darwin himself showed that 'thrumb-eyed' primroses set more seed than 'pin-eyed'. Dr. Simpson will therefore forgive me if I claim all natural selection as Darwinian.

Dr. Simpson has written a book which no biologist can afford not to study. He has written it in such a way that his meaning can never be misunderstood. This has meant very careful phrasing, and the reader will be all the more grateful to Dr. Simpson.

G. R. DE BEER

SUB-VITAL SYSTEMS AND THE ORIGIN OF LIFE

New Biology, No. 16

Edited by M. L. Johnson, Michael Abercrombie and G. E. Fogg. Pp. 135+8 plates. (Harmondsworth, Middx.: Penguin Books, Ltd., 1954.) 2*s*.

MOST of the sixteenth issue of "New Biology" is given over to discussion of the origins of life. Four articles deal with this perplexing subject, all of them showing that there is wide agreement on the main lines of thinking. Many years ago J. B. S. Haldane and A. I. Oparin suggested that the surface of the early earth could have given rise to a variety of organic compounds ready to give up their energy in a variety of reactions. Among the energy-providing materials 'sub-vital' systems are also needed which, using the energy provided, can grow and split and thus reproduce themselves. Now Haldane makes the important suggestion that complex phosphates may provide the basic mechanism, and he shows that this idea complies beautifully with the principle of continuity. J. W. S. Pringle, on the other hand, believes that the oxidation of hydrocarbons could have provided the sub-vital systems from the dynamic stability and potential growth of the complexes of intermediate substances which would be formed.

Two related problems which must be faced when such sub-vital systems are postulated are how the complex chains of reaction may be kept from disruptions by the turbulence of their surroundings, and how a concentration of organic substances approaching that of present living things can be achieved. Haldane has suggested water-logged soil as the first habitat; J. D. Bernal suggests adsorbed layers on clay.

Such sub-vital systems very probably appeared and disappeared in enormous variety. N. W. Pirie, in particular, emphasizes that present organisms are likely to represent the most successful one or few of many diverse kinds, a point of importance when deciding how best to begin the synthesis of living things. Pirie also emphasizes the entire arbitrariness of a decision as to whether a system is living or not. There would be no disputing the attribution of life to a growing and reproducing system kept firmly together by enclosure in a membrane. No useful hypotheses are yet available as to how this vital step occurred, probably, as Bernal suggests, because not nearly enough is known about existing cells. Haldane has suggested that a highly improbable event began the first cell and all organisms as we know them.

The present symposium shows that the topic of biopoiesis, as Pirie has called the 'origin of life', though it demands imaginative thinking, is certainly not a field for unrestricted speculation. Yet hypotheses are being produced which can be checked experimentally about some of the decisive changes postulated for the origin of life.

T. H. HAWKINS

A GUIDE-BOOK FOR WORLD CLIMATE

The Climates of the Continents

By W. G. Kendrew. Fourth edition. Pp. 607. (Oxford: Clarendon Press; London: Oxford University Press, 1953.) 50*s*. net.

THE fourth edition of Mr. W. G. Kendrew's masterpiece has appeared some thirty years after the first. The book has maintained its unquestioned place of honour throughout this protracted period. Few authors can hope to carry out, within their own life-times, four revisions of a standard book of reference, and to be assured thirty years from first publication that the book still leads the field. Practically all students of geography who have graduated from English-speaking universities during the past generation have been brought up on Kendrew's book, and it has received widespread recognition among meteorologists. It has few real competitors in the English language, for most text-books of climatology attempt a systematic rather than a regional approach. Only the Köppen–Geiger "Handbuch der Klimatologie" outweighs "The Climates of the Continents" as a regional encyclopædia of world climate. In a review of an earlier edition, *Nature* said simply that the book was . . . "the most useful and convenient collection of climatic data available in the English language", a view to which the present reviewer wholeheartedly subscribes.

In the fourth edition, the author has substantially revised the text, and has brought the tabulated climatic normals up to date. He has made a determined effort to incorporate the new ideas that emerged from the meteorological development during and since the Second World War. The text now contains explanations of certain regional climates in terms of the typical atmospheric circulation, including fronts, frontal cyclones and air-mass distribution. In the main, however, the treatment remains descriptive, and often leans heavily on long quotations from lay accounts of the climate—very often of its horrors. Though these eye-witness accounts enliven the reader's perception of the daily weather-cycle, they sometimes shock the susceptibilities of a scientific reader. J. M. Merk, who wrote in 1880 a description of the Punjab climate, is quoted on page 189 as saying that . . .

"Decaying vegetation under an ardent sun generates miasma, the consequences being fever, dysentery, and not infrequently cholera". Kendrew rarely or never comments upon, criticizes or corrects the laymen he quotes, and the effect is occasionally to give to his text a naïveté that is at once charming and disconcerting.

The book remains devoid of any attempts to classify climates generically, either in terms of an established taxonomy like those of Köppen and Thornthwaite, or in terms of the general circulation. The contents are treated in an alphabetical order (except for Australia and Antarctica, which unaccountably appear last). The entire effect is that of a guide-book for world climate, written in homely terms that render the text accessible to any educated reader. It is a tribute to Mr. Kendrew's achievement that this easy style, this freedom from technical parlance, in no way reduces the value of his book to a professional reader. Mr. Kendrew is to be congratulated on the longevity of his book, and we confidently expect, in due course, a fifth and perhaps subsequent editions. F. Kenneth Hare

RHEOLOGY OF FOODSTUFFS

Foodstuffs, their Plasticity, Fluidity and Consistency
Edited by G. W. Scott Blair. (Deformation and Flow: Monographs on the Rheological Behaviour of Natural and Synthetic Products.) Pp. xv+264+12 plates. (Amsterdam: North-Holland Publishing Co.; New York: Interscience Publishers, Inc., 1953.) 25 florins.

THIS book, like another in this series, is a collection of short monographs (eight chapters, varying in length from eleven to forty-five pages) devoted to the rheology of foodstuffs. The subject-matter is, as the editor states in the introduction, ". . . work at a comparatively early stage in scientific development" and a study which ". . . is still almost entirely at the empirical stage of development". It is not surprising, therefore, that much of the book is concerned with the results of these empirical rheological tests. The necessity for such tests is not questioned where the criterion of quality is frequently a subjective assessment of rheological properties made by the consumer on the finished product and where, in addition, many such similar judgments are made by the craftsmen in the industries concerned in order to pass on to the next process in manufacture. This book, therefore, summarizing as it does the existing state of practical rheology in some of the food industries, is a welcome addition to the literature. It is not, however, just a simple compilation of the results of the empirical tests; while it includes a description of these tests and the results obtained from them, every effort has been made to collate these results with other changes, physical, chemical and biochemical, taking place to give a complete, albeit qualitative, picture of the various processes occurring during manufacture.

The first chapter, on starch, by J. Hofstee and A. H. A. de Willigen, deals with pasting of potato starch and the properties of starch pastes in general. The mode of expression is at times unusual and the insert material is printed in different founts for no apparent reason. The following chapter, on cereals, by D. H. Greup and H. M. R. Hintzer, is devoted to the bread-making process and to the properties of dough. It presents a particularly lucid picture of the current state of knowledge in this field.

A short chapter on the rheology of milk, cream, ice-cream mixes and similar products, by G. W. Scott Blair, is primarily concerned with the viscosity of milk and the consistency of cream. The next two chapters—the consistency of butter, by H. Mulder, and the rheology of cheese and curd, by M. Baron and G. W. Scott Blair—are very similar in their approach: both give careful consideration to the effects of the processing on the finished products, in addition to discussing the various test methods available.

The rheology of honey, by J. Pryce-Jones, describes the effect of temperature on the viscosity of Newtonian honeys and the measurement of thixotropic and dilatant properties of the non-Newtonian honeys. The next chapter, on the rheology of certain miscellaneous food products, by H. G. Harvey, includes a summary of much of the work published in privately circulated bulletins by the British Food Manufacturing Research Association. Owing to the large number of products discussed, this monograph is not as valuable as some of the earlier ones.

The last chapter, on psycho-rheology, by R. Harper, reviews the work on subjective judgment of the rheological properties of some of the products dealt with in the earlier chapters of the book. The latter part of this chapter, devoted to factor analysis, is not clear, at least to one who is not familiar with the technique.

The literature references are collected together at the end, and these are followed by both author and subject indexes. In the latter the bold face type (the most important references) is not always clear; nor is the book free from typographical errors. The photographic reproduction is good, and the diagrams clear. J. E. Caffyn

ECONOMICS OF FUEL

The Price of Fuel
By I. M. D. Little. Pp. xiv+197. (Oxford: Clarendon Press; London: Oxford University Press, 1953.) 12*s*. 6*d*. net.

AS the author explains in the introduction to this volume, a book on fuel prices might well appear to need some justification, especially as the argument is largely concerned with an imposition of an increase in the price of coal. Indeed, many pages of close and able argument are devoted to an attempt to prove that this increase of price should be £1 per ton.

The study was written in the belief that the Ridley Committee had failed to deal with the pertinent evidence in support of this contention in an effective manner. Although a business man struggling to retain his foreign markets against rapidly growing foreign competition may be horrified by many of the arguments put forward, the book is a challenging analysis of the many complicated factors which must enter into any price structure concerning so important a national asset as coal.

The captious critic would say that it is a book for the planners, and would urge that the fuel world should be left alone to work out its own salvation. The author argues that the price of coal should be such as to permit of sales abroad and to supply a larger percentage of European consumption. The

home price should be raised to equality with the foreign price and kept equal to it. The increased revenue, some £150 million, should be put to various altruistic uses, such as general aid to the Welfare State, and particularly a rise in mining wages, the support of the sick and aged, family allowances and the development and use of approved domestic appliances for burning fuel. "Some slight turn of the inflationary screw" is regarded as harmless in comparison with the benefits foreshadowed.

Unfortunately, much of the carefully marshalled material and apparently logical argument is spoilt by a too rigid adherence to political dogma. There is lack of realism in the plea for the manipulation of electricity tariffs to put the electric fire out of existence. The ordinary man just will not accept it. Naturally, the evidence discussed is largely obtained from the literature of the subject, but in these matters, as in so many concerned with the world of affairs, the best knowledge frequently lies with the lifelong practitioners of the subject, and is not necessarily to be found in the books. Thus, the practice of fuel efficiency, sometimes described as the application of good engineering, was carried on in Great Britain long before the reports quoted. To make such an elementary error as to describe the Fuel Efficiency Committee as a "Council" resembles in its import the straw in the wind.

However, the book is an excellent essay in economic dogma, and there are so many interesting problems discussed that one may almost forgive the author for his dogma. The final chapters discuss such matters as the co-ordination of tariffs; that well-worn topic, a national fuel policy; and even nuclear power. To the reader genuinely interested in the subject, the book should certainly appeal for its wealth of material fact. The argument is a stimulating challenge at the present time and therefore to be welcomed.

R. J. SARJANT

DATING BY RADIOACTIVE CARBON

Radiocarbon Dating

By Willard F. Libby. Pp. vii+124. (Chicago: University of Chicago Press; London: Cambridge University Press, 1952.) 26*s*. net.

THE work of W. F. Libby and his collaborators during recent years has held out to archæologists and Quaternary geologists some possibility of absolute dating for organic materials from deposits between about A.D. 1000 and 20,000–30,000 B.C. Such was beyond our dreams a decade ago. Should this ideal be realized, it would very much enhance our understanding of the Pleistocene and immediate post-glacial periods, and, for lands of which the recorded history is of little antiquity, such as the New World, of the more recent past as well. The possibility of correlations of chronology between widely separated areas is also of paramount importance.

The results obtained up to the autumn of 1951 are brought together in this book. They have provoked much interest among archæologists, but are perhaps most of all a pointer to future possibilities, since the standard error for the method as deduced from them is of the order of ± 8 per cent (there are evidently uncertainties other than those due to counting random events in the Geiger counter) and, when comparisons are made between carbon-14 dates and those derived from archæological context, there are a number of 'rogues'. Moreover, the carbon-14 dates tend to be on the low side in the comparatively small number of cases so far studied in which a satisfactory archæological dating can be established. A number of effects may cause these low carbon-14 dates[1], such as bacterial or mould growth, or the penetration of minute rootlets into buried charred wood. It may thus be that for given materials and environmental conditions of survival there may be archæological half-life periods which are not absolutely identical with that of carbon-14 itself. It is not so easy to point out effects which may cause the carbon-14 dates to be too old, except the re-use in antiquity of organic materials already old, as 'bog-oak' is used to-day. In peats and muds such apparently enhanced antiquity may be due to percolation of water containing carbonates from old formations. It is evident that some materials give better results than others, wood being good and peats erratic, with the carbonate material of mollusc shells of dubious service.

As might be expected, progress in this field has been rapid, and even since this book was produced some refinements of method have been published[2]. Libby[3] has also given "a serious attempt to test the limit of sensitivity of the radiocarbon method", and a useful supplementary discussion of the errors involved, though the dating is again low as compared with the known limits of historical dating in this case, and his interpretation is open to criticism. Three replicate determinations were done on material from a carbonized beam from Nippur in Mesopotamia, the counting being prolonged in each case to one month from the usual forty-eight hours. These conditions of refinement yielded an overall standard error of the method of about ± 3 per cent. It is therefore clear that any really secure chronological framework which is to be built up from carbon-14 determinations must be based upon statistical interpretation of adequate data and should, for more biochemical reasons, be derived as much as possible from charcoals or cellulose or perhaps keratin material. What is now particularly needed is considerably more work on charcoal and timber samples which are closely datable archæologically, so that the method may be extended with greater precision and confidence to material of otherwise unknown antiquity; and there still remains the necessary investigation of possible fractionation of the carbon isotopes on incorporation into various phases of the biosphere, already demonstrated for carbon-13[4].

This book, though technical, is written in a commendably straightforward manner and should not be beyond the scope of any archæologist proposing to utilize carbon-14 dating in his work. Libby and his collaborators have earned much gratitude for devoting so many years of painstaking work to this programme, and it is a welcome sign that it now bears fruit in the appearance of data from other centres. It is much to be regretted, however, that British laboratories are only now beginning to make their rather belated start on this particular aspect of isotope research, though they have thereby the advantage of experience which has led to a number of improvements in method.

E. M. JOPE

[1] *Nature*, **166**, 756 (1950); *Antiquity*, **26**, 35 (1952). Zeuner, F. E., "Dating the Past", 343 (3rd ed., 1952).
[2] *Science*, **119**, 116 and 155 (1954).
[3] *Science*, **119**, 135 (1954).
[4] *Phys. Rev.*, **61**, 696 (1941); *Science*, **119**, 141 (1954).

THE DEVELOPMENT OF METEOROLOGY AS AN EXACT SCIENCE*

By Dr. O. G. SUTTON, C.B.E., F.R.S.

IT would be idle to pretend that meteorology, although it uses the language of physics and mathematics, has yet acquired the status of an exact science in all its branches. To take an obvious example, routine weather forecasting from the synoptic chart as yet involves very little actual calculation, and the reasoning with which the forecaster judges future developments is qualitative rather than quantitative, although it is essentially rooted in physics. My aim here is to attempt a critical examination of the part played by mathematics in meteorology—a stocktaking, to see how far the adjective 'exact' applies to meteorological science in the year 1954.

Mathematics has two main uses in applied science. The first is to provide an objective method of summarizing experience—to act as a 'memory'. This is what is done when an empirical formula is devised to represent, say, the rate of evaporation from a lake, or when a Fourier series is fitted to the diurnal variation of temperature. It is a humdrum use of mathematics, but essential in a subject such as meteorology, in which, at times, the sheer mass of observational data threatens to obscure the physical processes at work.

The second main use of mathematics in physical science is to make predictions. However, it is impossible to solve real problems of physics by mathematics; we can solve only certain ideal problems which have affinities with real problems. In many problems of physics the agreement between the numbers which appear in the mathematical solution and the pointer-readings of the laboratory instruments is so close that the illusion of having solved a real problem is almost overwhelming; but even in the simplest situations the agreement with observation cannot be perfect. In meteorology, the gap between the real situation and the ideal problem is much greater than in laboratory physics, so that it may appear sometimes that the mathematical meteorologist scarcely lives in the same world as his 'practical' colleague; but the difference is one of degree only, and not of principle.

A science may be regarded as 'exact' when it is possible to make observations of high precision on the state of a system, and when the solutions of certain mathematical problems correspond closely to the numbers indicated by physical measurements. How close the correspondence needs to be is largely a matter of judgment, based on the reliability and objectivity of the observations. Obviously, the criteria which apply to, say, spectroscopy are much too severe for meteorology, and we may be well satisfied with a meteorological 'theory' in which the difference between the observed and calculated values is not more than, say, 10 per cent. There are very few meteorological theories which satisfy this criterion at the present time.

Nature of the Meteorological Problem

Meteorology is concerned with physical processes taking place in the atmosphere, a shallow ocean of gases held to the surface of the earth by the force of gravity. The first picture of the atmosphere is that of a shallow gaseous fluid heated from below, which immediately suggests certain problems in natural convection that, to date, have yet to be solved satisfactorily even for the relatively simple conditions which can be realized in the laboratory. (In addition, there is the very significant complication that the convective system is based on the spinning earth.) For the meteorologist, the most important constituent of the atmosphere is water vapour, which supplies an effective means of taking up and releasing heat in enormous quantities. The result is to complicate tremendously the convective system formed by the sun, the atmosphere and the earth's surface. The system, which can scarcely be isolated from the universe as a whole, is one in which the state of the lower boundary influences, and is influenced by, the condition of the gaseous fluid resting upon it. The meteorologist thus has to deal with the vagaries of an open system which is strongly cross-linked. Almost every element of the system reacts significantly with every other, and non-linearity, the bugbear of the mathematician, is the rule rather than the exception. There is a strong temptation to propound soluble problems in physics which have some relation to atmospheric processes and to call the result 'dynamical meteorology'—a type of academic exercise which is only too familiar in the older books on the subject. The real advances are not made in this way, and the essential step lies in discovering the framework of the real problem. It is unprofitable to formulate first an artificial but soluble problem and then to look for occasions when the atmosphere appears to conform.

We may distinguish two classes of problems in meteorology. In the first class are problems, like evaporation, which have nearly everything in common with laboratory problems except the possibility of complete control. In the second class are problems which have little or nothing in common with laboratory experience, such as those which appertain to the development and movements of the large-scale pressure systems of the middle latitudes. Mathematics can be applied with profit in both classes, but with very different criteria of success.

Evaporation

Evaporation is a typical problem of the first type, which can be approached in two different but legitimate and profitable ways: (i) by an examination of the mechanism of the process, disregarding the economics, and (ii) by evaluating the energy balance, disregarding the mechanics.

Evaporation from a semi-infinite area poses a typical boundary-value problem, of a type familiar in the theory of conduction of heat. The earliest treatment is that of Jeffreys, in which the total evaporation from an area extending a known finite distance downwind is given by an explicit expression involving the wind speed, dimensions of the area and the eddy conductivity K. If K were a true universal constant, knowledge of the wind speed, the relative humidity, temperature of the surface and the size of the area would enable the meteorologist to calculate

* Substance of the presidential address delivered before the Royal Meteorological Society on April 28.

the amount of water carried over the downwind edge of the area in a given time; but this solution cannot be used to make predictions, because of the uncertainty regarding the value of K. In 1934 I published an extended treatment of the semi-infinite area problem, which took into account the variability of wind speed with height and expressed the effect of turbulence, not by a fictitious constant, but in terms of measurable quantities. This solution could be used to make predictions, and soon afterwards Dr. F. Pasquill showed that the measured total of evaporation from small saturated surfaces agreed with the mathematical forecast to within about 10 per cent.

At this stage in the investigation this work was not peculiarly meteorological, for the mathematical treatment and the subsequent verification were all on lines familiar in any physical problem. Since then, there has been one notable attempt, in America, to extend the investigation to the meteorological scale, at Lake Hefner, in which it is concluded that two of the theoretical formulæ tested "gave good results" in predicting the rate of evaporation from measurements of wind, temperature and humidity.

The study of evaporation is instructive because it illustrates very clearly the way in which laboratory physics of the orthodox type merges into meteorology, but with a substantial loss of precision as it does so. This particular problem, approached in the classical manner, is yielding to research in a fashion well known to scientists since the seventeenth century, and there can be little doubt that as we discover more about the mechanics of turbulence we shall get better agreement. All observations of physical quantities contain random fluctuations covered by the generic term 'noise', which limit the precision with which the result can be stated. The mathematical problem effectively relates to an ideal, noise-free system. In meteorology, the 'noise'-level is always much higher than in laboratory physics, and meteorologists must accept as satisfactory agreement between quantities which are, to the laboratory physicist, rather crude averages.

The alternative way of attacking this problem would scarcely recommend itself to a laboratory physicist, but it has considerable merits in meteorology. The 'energy-balance' method consists in first evaluating or estimating all the terms in the transformation of energy except one, that which represents the heat used up in evaporation, which is finally determined as a difference. This method also has given good results.

Evaporation is typical of a large class of meteorological problems in which one may look forward with confidence to ultimate success. In such studies the state of the atmosphere is prescribed, and it is asked how this affects certain physical processes. Provided that a sensible view is taken of the desirable accuracy, there seems to be no reason why such questions may not be finally settled. It is otherwise with problems arising in the phenomenon of weather.

Mathematics in the Synoptic Problem

The central problem of meteorology is that of forecasting weather. Attempts to bring this within the discipline of mathematics have been, in the main, by the study of 'model' atmospheric disturbances, by statistics, and by the equations of hydrodynamics. Analyses of synoptic situations based on analogies with motions studied in the classical hydrodynamics flourished in the early years of this century. Such 'mechanical' models are now of historical interest only. They represent an excessive idealization, for essentially they are two-dimensional models given a three-dimensional appearance.

The three-dimensional character of the middle-latitude disturbance begins to emerge, however, in the Norwegian concept of the evolution of the depression as a development of wave-like perturbations of the polar front. We know now that the true Bjerknes depression is somewhat rare, and that the sequence of events described in the earlier papers represents a very considerable idealization of what actually occurs; but even so, there is every reason to be grateful to the Bergen school for showing, by precept and practice, the value of air-mass analysis in routine forecasting.

The statistical approach has attracted, possibly, more workers than any other; but to-day it is doubtful if anyone (apart from a few enthusiasts) would claim that the results obtained are commensurate with the effort expended or that the method merits further serious study. The search for empirical periodicities and correlations is not only unsound but also dangerous, in that it tends to create a state of mind approaching that of the 'true believer', who sees examples to support his creed in every case he examines. As regards the possibility of using harmonic analysis in forecasting generally, the conclusion seems to be that the application of statistical theory to pressure–time series for the purpose of forecasting weather is a misuse of a mathematical tool. The prime purposes of statistical theory are to examine data for internal consistency and to weigh the evidence for a previously formulated hypothesis; and in meteorology, as in any other science, it is essential that the research have a sound physical basis before any statistical approach is attempted.

The 'mechanical model' and 'statistical' methods represent two widely different approaches. There is, however, a middle way which seems to hold out considerable hope, namely, the direct attack on the problem by means of the equations of hydrodynamics. The limitations of the method are very serious. It is not so much the complexity of the situation which appals the mathematician, but the fact that the problem may be indeterminate. It seems that at times the initial conditions may be insufficient to determine a unique solution. The atmosphere is so nearly unstable that disturbances which are below the threshold of observation at one time, or which are so small initially that they are removed in the necessary process of smoothing, can grow exponentially and affect the distribution significantly at some later time. Also, it is not yet known how far unpredictable astronomical events, such as bursts of cosmic radiation, sunspots or meteoric showers, may affect the macro processes of the atmosphere. If they are capable of causing significant changes, it follows that weather is really indeterminate, for some at least of these phenomena are the result of occurrences which took place æons ago deep in the remote universe.

In routine forecasting, the weather prognosis is built around the time-extrapolation of the existing pressure fields, a process which is highly subjective. In deciding how the air masses will rearrange themselves in the course of the next twenty-four hours, the forecaster may be guided by the properties of a model, such as the Bjerknes depression, by considerations of the topography of the pressure surfaces,

or by a set of private empirical rules which constitute his 'experience'. Whatever method is adopted, it is evident that good judgment and long practice are essentials in this difficult art. The mathematical method should be regarded as a means of indicating the most *probable* line of development. It seems that we should be unwise to expect more than this, at least for some years to come.

Ideally, any system of mathematical prediction should be based on conditions over the whole globe; but in practice, for a 24-hr. forecast in Britain, it is sufficient to restrict the calculations to the movement of air masses over a rectangle covering part of the eastern Atlantic and part of western Europe. The distribution of air pressure at the surface and at some considerable height in the troposphere is known tolerably well within this rectangle at any one time. With a conventional 'lid', say, at the tropopause, and the assumption that conditions do not change (or change according to some prescribed law) at the boundaries of the rectangle, the problem amounts to tracing the movements of the air inside the box formed by the rectangle, the vertical walls and the 'lid' in a period of, say, twenty-four hours. In other words, we set up a model atmosphere which obeys certain simplified forms of the laws of Nature, but we are not restricted to a rigid model of an anticyclone or depression in the sense used earlier.

This particular model, like many others, is a compromise. For some time to come meteorologists must be prepared to accept models which are not strictly logical, in that there is an arbitrary selection of certain features to be retained, while others are rejected, not necessarily because they are small but because their retention would make the model unworkable. As in mathematical physics generally, such models are idealizations, useful but not easily justified on strict mathematical grounds. It is important to realize that in such investigations there is no attempt to produce a forecast of weather. Attention is limited to an examination of the pressure and motion fields over a relatively small part of one hemisphere, in the middle latitudes. Even if the method were infallible (which it is not) the services of the meteorologist, as distinct from the mathematician, would still be required to 'put in the weather', a phrase which covers what may well be the most difficult part of the whole process of forecasting. It will be the responsibility of the forecaster, drawing on his experience, to accept or reject the answer provided by the mathematicians, and he must always recognize that the subjective element has not been eliminated by the mathematics but removed a stage farther back, to the initial postulates of the model.

The numerical method has been tried by the Meteorological Office, so far, on a few occasions only. The results are encouraging. The charts produced by the machine for the surface and the mid-troposphere have reproduced the main kinematical features of the real situation; they are about as good as those which were drawn by experienced forecasters on the dates in question. Thus, while it is far too early to claim that the value of the method is established, there are good grounds for continuing the research.

Conclusions

The fact that a weather forecast is essentially a statement of chances is not fully appreciated by the non-meteorologist, and some of the distrust with which the forecasts are regarded can be attributed to this misunderstanding.

The task of the meteorologist does not finish with the composition of the forecast—there is still the very important problem of conveying the results of the analysis to the public in simple and straightforward terms; and this part of the problem is almost as important as the examination of the physical processes at work.

NATURAL MAGNETIZATION OF IGNEOUS AND SEDIMENTARY ROCKS

A DISCUSSION of recent developments in Great Britain in the study of the permanent magnetization of rocks was held during January 8–9 in the Geology Department of the University of Birmingham. The chair was taken at the three sessions in turn by Prof. F. W. Shotton (University of Birmingham), Prof. O. T. Jones (University of Cambridge) and Dr. J. McG. Bruckshaw (Imperial College of Science and Technology, London).

The permanent magnetization of rocks is due to the ferromagnetism of their iron oxide minerals. Dr. G. D. Nicholls (Department of Geology, Manchester), in summarizing what is known of their mineralogy, pointed out that they are often loosely classified as 'magnetite', but it is important to know their exact composition, on which their magnetic properties are very dependent. They occur naturally as solid solutions of hæmatite (Fe_2O_3, rhombohedral), maghæmite (Fe_2O_3, cubic), magnetite (Fe_3O_4, cubic) and ilmenite ($FeTiO_3$, rhombohedral), of which the first three are ferromagnetic. The known range of solid solution is most simply expressed by the ternary FeO—Fe_2O_3—TiO_2 diagram, shown in Fig. 1.

The full lines represent known solid solutions; the dotted line is conjectural but probably represents qualitatively the boundary of a region of no solid solution at magmatic temperatures. There is evidence that the size of this region increases with decreasing temperatures, leading to exsolution on cooling and the existence of two phases in the resulting mineral grains. In slowly cooled basic rocks minerals of the magnetite–ulvöspinel series seem to be most common, whereas in those which have been rapidly chilled minerals occur the compositions of which are inter-

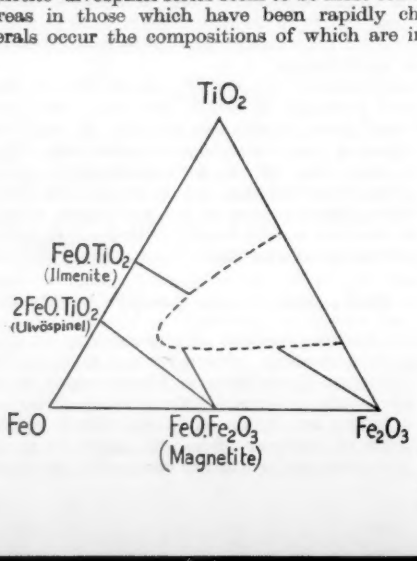

Table 1. Effect of Ionic Replacement on the Curie Points of the Iron Oxides

Mineral	Ion replaced	Replacing ion	Upper limit of replacement (per cent)	Change of Curie point (°C.)
αFe_2O_3	Fe^{+++}	Al^{+++}	5	675 → 611
γFe_2O_3	Fe^{+++}	Al^{+++}	5	small
Fe_3O_4	Fe^{+++}	Al^{+++}	15	575 → 535
		Cr^{+++}	18	575 → 560
Fe_3O_4	Fe^{++}	Co^{++}	100	575 → 520
		Ni^{++}	100	575 → 595
		Mg^{++}	100	575 → 315
αFe_2O_3		Mn	about 80	675 → 140

mediate between magnetite and ilmenite. It appears that the ore minerals of basic lavas are richer in titanium than those found in acid lavas.

Dr. Nicholls then explained that partial replacement of iron by other ions in these minerals is possible and affects the Curie point. The changes he listed are shown in Table 1.

The introduction of sodium ions into magnetite has been reported to a limit of 6–7 per cent $Na_2Fe_2O_4$ in Fe_3O_4 (replacement of Fe^{++} by $2Na^+$?), the Curie point being lowered from 575° to 535° C. Replacements of iron ions by sodium is also possible in maghæmite, and with 5 per cent of Na_2O present the Curie point becomes 415° C. A possible replacement of Fe^{+++} Fe^{++} by Na^+Si^{++++} in magnetite is considered to be more likely in natural ore minerals than a straight replacement of Fe^{++} by $2Na^+$. The reduction of Curie point which can be brought about by replacement is of interest in view of the range of Curie points which have been reported for some rocks.

Dr. Nicholls then explained that minerals exist with very abnormal magnetic properties. The ferromagnetic components of the dacite pumice from Mt. Haruna, Japan, have been separated by Nagata[1] into three fractions, *A*, *B* and *AB*. *A* is fairly pure magnetite; *B* is similar in composition and structure to ilmenite, but is ferromagnetic and has a Curie point of about 300° C. *AB* has the remarkable property of reversing its polarity on cooling. Nagata interprets it as an intergrowth of *A* and *B*; but examination under the ore microscope fails to reveal this so far. It is possible that the rhombohedral phase reported in *AB* originated through physical changes produced during thermomagnetic separation; but it is not likely that the properties of the *AB* fraction can be explained solely in terms of ionic replacement in a cubic ferromagnetic phase.

Some experiments described by Dr. Bruckshaw confirm the existence in igneous rocks of minerals covering a wide range of Curie points. He has carried out a separation of the various ferromagnetic constituents of his specimens according to their Curie points, which he finds to be mainly in the range of 300–600° C., and, of eight fractions separated, four have Curie points in the 500–600° C. temperature range.

The question of the origin of the reversed magnetizations found in many rocks was continually arising in the discussion. Evidence in favour of their being due to a real reversal of the earth's magnetic field was put forward by Dr. Bruckshaw, who described careful measurements of the thermoremanence acquired by Tertiary lavas from Mull in fields from 1 gauss down to 0·02 gauss. These observations show no evidence of reverse magnetization, so that the rocks possess no property similar to that of the Haruna dacite described by Nagata[1], in which the magnetic polarization acquired near 600° C. changes sign on cooling at about 300° C. Further, it is apparent that the natural remanence of the Mull lavas could have been acquired in a reversed field comparable in intensity with that of the present field.

Dr. S. K. Runcorn (Department of Geodesy and Geophysics, Cambridge) described measurements he has made, in co-operation with Dr. C. D. Campbell, of the State College of Washington, Pullman, on the Miocene lavas of the Columbia River of the north-western United States. In series of flows at different localities are found groups of normally and reversely magnetized lavas (cf. those of similar age found by Hospers[2] in Iceland). Dr. Runcorn agreed with Hospers's interpretation that these series of reversed and normal flows indicate that the earth's field has been constant in direction for periods of hundreds of thousands of years, but has suffered reversals which took place in a few thousand years. This would be consistent with the probable relaxation time of the current systems postulated in present theories of the geomagnetic field. In reply to exponents of the various mechanisms of self-reversal put forward by Néel[3], Nagata[1] and Graham[4] to account for reversed magnetizations, Dr. Runcorn objected that some modern lavas should possess reversed magnetization if such mechanisms were not exceptional. Further, only three rocks[1,5] and one synthetic spinel[6] show self-reversal in the laboratory, in contrast to the large number of reversed magnetizations found in the field.

Both in these measurements on igneous rocks, and in those on sediments which were described later, the scatter in the direction of magnetization is usually very wide. In these circumstances the assumption that the components of declination and inclination are separately distributed in a Gaussian manner is invalid. Sir Ronald Fisher (Cambridge) described how he had developed the statistics of dispersion of points over the surface of a sphere[7], based on the function $\exp(\varkappa \cos \theta)$, where θ is the angular error, and $\varkappa$ is a measure of precision. He described how to derive from this distribution function the radius of a 'circle of confidence' within which the mean direction would be expected to lie with any desired probability.

Dr. J. Hospers (Bataafsche Petroleum Maatschappij, The Hague; formerly of the Department of Geodesy and Geophysics, Cambridge) described an application of this statistical treatment to a set of measurements made by several different workers on Tertiary igneous rocks. He has found the probable position of the magnetic pole at various geological periods and the radius of the circle of confidence for each result. He concluded that there is no evidence for the large 'polar wandering' suggested by Wegener and others for comparatively recent geological times, but that there is some indication of a 5° movement of the pole since Eocene times[8].

Information on the direction of magnetization of sediments was presented, which covered the whole range of the geological column. Mr. E. Irving (Department of Geodesy and Geophysics, Cambridge) described measurements on silt and fine sandstone specimens collected from sixty-three localities in a 9,000-ft. thick stratigraphical succession in the Torridonian of north-west Scotland. Of these, thirty-seven have a magnetization directed towards the south-east with a downward inclination, sixteen have north-west directions with an upward inclination, and ten localities show oblique directions. The

mean directions of magnetizations of the first two groups are :

	Declination (east of True North)	Inclination
South-east localities	122°	+ 49
North-west localities	292°	− 33

The localities are grouped into sixteen zones with alternating south-east and north-west magnetization, these varying from 100 ft. to 2,000 ft. in thickness. With one exception the localities with directions oblique to the general axis of magnetization occur between zones of opposed magnetization and are probably in some way transitional. (A study of the magnetization of Torridonian pebbles in conglomerates of New Red Sandstone age, and of beds folded during the Caledonian orogeny, shows that these directions have remained unaltered for at least 10^8 years.) Mr. Irving's work on the Torridonian included an interesting study of the directions of magnetization of these siltstones in both small- and large-scale slumps. In the former, the directions he measured are practically random, as though the magnetization took place at deposition and the directions were randomized by the slumping. Specimens from the large-scale slumps, on the other hand, show uniform magnetization, implying that the beds were magnetized or remagnetized after the slumping had taken place.

Mr. K. M. Creer (Department of Geodesy and Geophysics, Cambridge) produced data for sediments from the Devonian, Triassic and Eocene periods, and from the lava traps of the Exeter Volcanic Series of Permian age. Rocks from both the Lower and Upper Old Red Sandstone all show reversed polarizations, the declination on the whole being just west of south and the inclinations extremely shallow. The Exeter Traps are also reversely magnetized along the same horizontal axis but with slightly greater (although still small) inclinations. Samples taken from a 110-ft. cliff of Keuper Marl (Triassic) at Sidmouth, Devon, are only partially stable, but even so there is strong evidence for magnetization along a north-east–south-west axis. The upper and lower portions of the cliff are normally polarized, but the middle 34 ft. is reversed. The Bagshot Sands (Tertiary) give directions not very different from the present earth's field.

Mr. Creer found that the magnetization of his Keuper Marls was partially unstable, the measured directions being affected only slightly by the horizontal component of the earth's field but appreciably by its vertical component after only a few weeks in the laboratory. All these rocks contain a red-staining mineral, probably hæmatite, and the presence of this mineral leads to a high coercivity of several thousand gauss. Bleached specimens of the same marl have coercivities an order of magnitude less than this. The instability is not, however, associated with low coercive force or with absence of the red component. It was found, rather, that stable and unstable specimens contained about the same amount of the red mineral, but that, in general, the unstable rocks were less strongly magnetized than the stable ones. It might be, then, that the magnetization due to the red mineral is essentially unstable, and that the more stable specimens contain a greater proportion of a magnetically stable material, which would account also for their greater intensity. In the weakly magnetized specimens, on the other hand, there would be insufficient stable material to mask the instability of the red mineral. Mr. Creer explained this paradoxical association of high coercivity and instability in terms of Néel's theory of the magnetic properties of particles small enough to be single ferromagnetic domains. Néel has shown[9] that such particles can have long relaxation times and therefore be magnetically stable, if their volume is greater than a lower limit set by the demagnetizing effect of thermal fluctuations. On the other hand, extremely small particles will be unstable because of their short relaxation times, even though their coercive force is very high. Mr. Creer has estimated that the particles of his red mineral were of this size and, in support of his explanation, has extended to the case of ferric oxide Néel's calculation of the relaxation time for iron particles. He has found that, to have a relaxation time of the order of thousands of years, the ferric oxide particles would have to be too large to be single domains. This implies that for ferric oxide there may be no 'stable range' of particle size limited at the lower end by the effect of thermal fluctuations and at the upper by the appearance of domain boundaries in the particle.

Commenting on these palæomagnetic directions, which span much of geological time, Dr. Runcorn said that reversed polarizations seem not to be confined to Tertiary strata or to igneous rocks, in which they were first studied. The processes generating the main field are now sufficiently understood to make reversals of its polarity scarcely surprising. In addition to the external field, there is reason for believing in the existence within the core of much stronger toroidal fields[10] to which the former owes its origin. Reversals of the dipole field may not involve reversals of this toroidal field. The coincidence of the magnetic and rotational axes through Tertiary times, covering many reversals, is explained by the dominance of the Coriolis force on motions within the earth's core and is thus likely to be true in other eras. Thus an additional hypothesis is necessary to explain the palæomagnetic directions in pre-Tertiary times. Dr. Runcorn considers that movement of the earth's surface relative to the axis of rotation in space is the simplest suggestion. The 'polar wandering' inferred from the measurements in Britain for each geological epoch should be tested by measurements on similar formations in other continents.

Dr. J. A. Clegg (Imperial College of Science and Technology, London) gave an account of measurements on rocks from ten sites in the Keuper Marl Series, covering the lateral extent of this Series in England from Carlisle and Yorkshire down to Devonshire. In five of these sites the rocks are polarized approximately 40° east of north and with downward dips of 30–40°. In four sites the polarization is almost exactly reversed, being to the south-west and with upward dips of similar magnitude. In the tenth site at Sidmouth, Devon, the magnetization of the rocks is found to be unstable in the earth's field. Further measurements on Lower Old Red Sandstone rocks from Gloucestershire and Upper Coal Measure rocks from Bristol show that these have the same axis of polarization.

Demagnetization tests on specimens in alternating and steady fields at various temperatures varying from 0 to 600° C. show that there are two magnetic constituents present in the rocks. The first or 'soft' component is easily magnetizable by d.c. fields of the order of a few gauss at room temperature and by the earth's field at temperatures greater than 80° C. It can be demagnetized by relatively small a.c. fields. The second or 'hard' component is stable

in fields of the order of hundreds of gauss and at temperatures as high as 500° C.

This uniformity of magnetization combined with high magnetic stability of rocks ranging over such a wide geographical area and geological age evidently has some physical significance. Dr. Clegg considered a number of possible reasons for this preferential direction of the magnetic polarization and concluded tentatively that it might be due to a movement of Britain relative to the earth's geographical axis.

The most recent sediments measured are some post-glacial varved clays from Sweden. Dr. D. H. Griffiths (Geology Department, Birmingham) described measurements on two contemporaneous series of these clays from localities several miles apart on the Ångerman River. The directions of magnetization show a regular variation suggestive of secular variation, and, over the 500-year period of overlap between the two series, good correlation of the directions is obtained, provided that corrections for the geological dip of the series are applied, amounting in one instance to 13°. Unfortunately, there is no supporting geological evidence for the validity of this correction. Dr. Griffiths also described measurements on recent varved-clay core samples obtained from the Ångerman River delta with a non-magnetic Kullenberg core-sampler carrying a device for recording sample orientation. More than a hundred samples were measured covering the period A.D. 1400–1900, and it was therefore possible to compare magnetization directions with observatory records of the earth's field for this period. There was a rather large scatter in the measurements and average values of sets of samples had to be taken. The directions of the horizontal components of magnetization of the samples showed good agreement with the earth's field for corresponding periods, but inclinations were very variable and inconsistent. Correction for the small geological dip of the beds tended to improve correlation. These results were not altogether in agreement with measurements on the older varves, which were from the same general area, for in the older varves the evidence suggested that both declinations and inclinations were reliable.

A laboratory experiment showing how magnetization of sediments was acquired on deposition was described by Dr. R. F. King (Department of Geology, Birmingham). He had redispersed some of the Swedish varved clay on which Dr. Griffiths's measurements were made, and had allowed it to settle slowly in the field of the earth. The direction of magnetization of this artificial sediment was not appreciably altered by the later application of a field in a different direction, although this was done while the clay was still under water and completely unconsolidated. Dr. King also described other experiments on re-sedimentation of clay, discussing in particular the discrepancy between the inclination of the remanence of the sediment and that of the applied field. This discrepancy has been noticed by other workers both in the laboratory and in the field, and is generally thought to be due to elongated or flattened magnetic particles tending to settle with their long axis or axes horizontal. Dr. Clegg, who had also noticed the effect, suggested that it could be due to rotation of the particles during the early stages of compaction. He described also an experiment in which a post-depositional field was applied to artificially deposited Keuper Marl. In contrast to the result of Dr. King's experiment, the direction of magnetization was found to rotate into that of the new field. The water content of his deposit was, however, considerably greater than that of the freshly deposited Swedish clay.

The various contributions to the meeting showed that over the past year or two our knowledge of rock magnetism has greatly increased. Yet, despite the large number of observations that have been collected, it is obvious that many important problems will have to be solved before any general criteria of reliability can be established for rock magnetism measurements. For example, there is still some conflict of opinion on the question of reversed magnetization. There is also, as yet, no direct way of testing the stability of rock magnetization, though there is sometimes good indirect evidence of this. Finally, as model experiments are beginning to show, there is still much to be learned about the method by which the magnetic moment is acquired.

D. H. GRIFFITHS
R. F. KING

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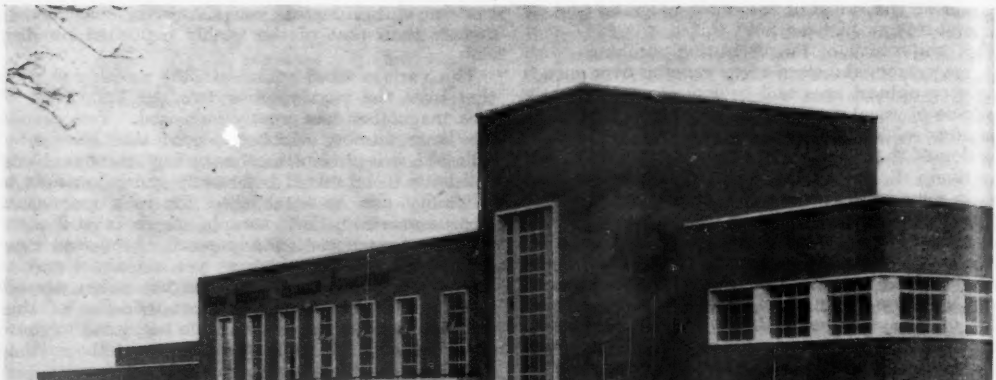
NEW LABORATORY OF THE MOTOR INDUSTRY RESEARCH ASSOCIATION

By DR J. R. BRISTOW

THE Motor Industry Research Association's new Laboratory, together with the Proving Ground, was officially opened on May 21 by the Minister of Transport, the Right Hon. Alan Lennox Boyd, in the presence of distinguished guests, representing the motor industry, universities and Government departments, and some twelve hundred visitors.

The Laboratory stands on an 11-acre site in the angle formed by the Watling Street (*A5*), and a private road leading to the Association's Proving Ground, at Lindley, near Nuneaton. The Laboratory, which has a floor area of about 30,000 sq. ft., together with other buildings (canteen, garages and workshop) having a total floor area of about 10,000 sq. ft., occupies about half the site, thus providing room for considerable future expansion.

The lay-out of the main building is based on a wide *L*-shaped corridor with offices, conference room, drawing office, entrance hall, etc., on the 'outside' of the corridor forming a main frontage, about 300 ft. long, parallel to the Watling Street, and a subsidiary frontage, about 125 ft., parallel to the private road to the Proving Ground. The separate research laboratories—electronics, metallurgical, general engineering, engine, machine shop and stores—consist of open wings (with windows along both sides and roof lights) leading off at right angles from the longest corridor. There are no small separate rooms for research purposes, a small number of large open floor spaces being more suited to the Association's needs than a large number of small restricted floor



New Laboratory of the Motor Industry Research Association

areas. The building is of steel-frame brick-panel construction. That part of the structure consisting of offices, library, etc., is two-storied, the first floor and roof being of hollow-tile construction with space-heating by low-temperature ceiling panels. All the research floor area is at ground-floor level only, with steel deck roofing and high-temperature radiators for space-heating. (The boilers for space-heating are oil-fired and automatic.) Lighting is by tungsten lamps throughout the building except in special cases, for example, the drawing office and measuring room.

The Electronics Laboratory is 50 ft. × 30 ft.; a wall bench and an island bench give working space for nine people and are well supplied with a.c. and d.c. points; there is a stabilized high-tension power supply to each work space. Two other wall benches are set aside for metal working and for calibrating instruments against laboratory standards. The laboratory is well equipped with oscillators, valve voltmeters, oscillographs, etc. The purpose of the Electronics Section is to design and construct special equipment for the Association's work in general, and to undertake the study of problems in which instrumentation is the major feature, or which are 'physical' rather than engineering in nature, for example, the study of noise in vehicles. In connexion with this latter, there is attached to the Electronics Laboratory a 'noise-room', large enough to accommodate a motor-car, in which all internal surfaces are treated with wedges of noise-absorbent material giving 'free-field' conditions over a wide frequency-range. Examples of the type of equipment developed in the section are torque-meters for measuring steering torque and axle torque, accelerometers, dynamic strain-recording equipment suitable for use on the roads with wire-resistance strain-gauges, and noise-recording equipment.

The Metallurgical and Chemical Laboratory contains two island benches (one for assay and one for metallography), wall benches, fume cupboards and temperature-controlled furnaces, polishing machines, etc. There is also a balance room, and a small dark room situated conveniently next to a Vickers projection metallurgical microscope.

The General Mechanical Engineering Laboratory is a large open space 100 ft. × 58 ft.; in it all the experimental work requiring mechanical 'rigs' is carried out, save that involving the power-unit (see later). A large section of the Association's work involves the study of fatigue strength of materials and components, and fatigue machines at present housed in this Laboratory are for bending and torsional fatigue of crankshafts (4), small Wöhler machines (2), hydraulic pulsators for fatigue testing of gear teeth (2), and power circulating gear machines (2) for the study of 'pitting' (surface fatigue). Generally it is desirable to carry out measurements using specimens in the shape of the actual components, particularly in the case of castings, and it is even necessary in investigations into the effect of materials and methods of manufacture to use specimens of component form. Hence the machines are predominantly for fatiguing components, rather than of the type which take laboratory specimens. Other apparatus in this Laboratory concerns the operation of brakes. A machine for studying 'fading' of brakes (that is, changes of coefficient of friction with temperature) is essentially a rotating drum, the temperature of which can be controlled, against which a piece of lining material is pressed in such a way as to give no 'servo' action. Apparatus for turning a road wheel continuously with the brakes applied and with means of recording brake pressure, friction torque and temperature is for the study of the mechanism of brake squeak. Within this Laboratory is a measuring room, housing measuring instruments and standards, Vickers hardness machine, involute tester and surface roughness measuring equipment, and also a dark room containing an N.P.L. type profile projector.

The Engine Laboratory (88 ft. × 30 ft.) has eight fully equipped engine test bays. The walls, ceilings and partitions of the Laboratory are treated with sound-absorbing material; and the walls are not directly connected with the rest of the building, so as to reduce transmission of noise and vibration. Engine stands and dynamometers are mounted together on large concrete beds which are cushioned on rubber to reduce vibration transmitted to the floor. Three beds have electric dynamometers and the other five water brakes. Fuel lines (diesel and petrol) run to each bed, together with water and electric power. As well as investigations concerning the operation of the power-unit as such, any work involving the running of an engine under power is carried out in this Laboratory; for example, the measurement of loads in crankshafts (in progress at the time of writing) using wire-resistance strain-gauges attached to the shaft.

The workshop, which is fully equipped to undertake all the Association's needs for special apparatus, instruments and test specimens, is 100 ft. × 29 ft.; and there is a general stores of similar size. There is a small drawing office (50 ft. × 20 ft.) and photographic rooms (40 ft. × 22 ft.). The conference room, which is equipped for the projection of 35-mm. sound films and lantern slides from a projection room outside it, is 46 ft. × 22 ft. In addition to the library (40 ft. × 22 ft.), in which only bound volumes are kept, there is a library store (46 ft. × 22 ft.) for unbound literature. Through the Information Section about 7,000 loans of technical literature are made each year, and for documents in great demand a photo-copying service is operated.

Obviously, much of the Association's research work, such as that connected with stresses in vehicle structures and noise in vehicles, has to be carried out on the road, and the Proving Ground provides private roads for this purpose. In addition, the Proving Ground has been equipped with features which make it a testing ground on which manufacturers can prove their vehicles, as well as using it for development and research work which would otherwise (and less conveniently) have to be carried out on public roads. The Proving Ground covers nearly 650 acres, with 12½ miles of track and special road surfaces; features include a banked circuit on which high speeds can be continuously maintained; a pavé track which is used for accelerated endurance tests on complete vehicles; a corrugated track which reproduces the well-known non-metalled 'washboard' roads of tropical and sub-tropical countries; a 'water splash'; a 'dust tunnel' for studying dust entry, etc.

NEW BUILDINGS FOR THE UNIVERSITY OF GLASGOW

AT a ceremony held in the Bute Hall of the University of Glasgow on March 19, the Right Hon. James Stuart, Secretary of State for Scotland, inaugurated the new buildings which have been erected for the University since the conclusion of the Second World War. Some of these buildings are not yet complete, but they are all in use. There are six entirely new buildings, ranging from the final block of the new Chemistry Institute, with a floor area of more than 80,000 sq. ft. and costing more than £500,000, to a small extension of the Zoology Department, with a floor area of some 5,600 sq. ft. and built at a cost of £24,500. In addition, there have been major works of reconstruction and adaptation which have provided increased accommodation and more modern facilities for the University Offices and for the Departments of Bacteriology, Biochemistry, Botany, Genetics, Mathematics and Pharmacology. Also, a factory has been purchased and is being converted into a research block for mechanical engineering. In all, these new buildings and reconstructions have cost about £2 million, of which more than 90 per cent has been provided from public funds.

The most mundane of these projects is the new boiler-house (architects: Messrs. Gillespie, Kidd and Coia). This had become necessary not only because the old boilers were on the verge of complete breakdown, but also because they were quite unable to meet the demands of the new buildings in course of construction on Gilmorehill. Construction of the new boiler-house involved a difficult and costly excavation of the hillside. The northern side of the roof is on a level with the adjoining roadway and on the roof itself are two excellent tennis courts. Three Penman's economic boilers have been installed, each of which can give 12,500 lb. of steam per hour. The fuel store takes 560 tons of coal, which is fed to the stoker hoppers by coal elevators. The only man-handling needed is in raking out the ash, and the efficient operation of the plant is assisted by the usual automatic recorders. Considerable economy in fuel has resulted from this installation.

The new extension for the Department of Natural Philosophy (architects: Messrs. Basil Spence and Partners) is more advanced in its architectural conception than any other of the University buildings. It provides increased and modern facilities for research in both experimental and theoretical physics. The rectangular main block, consisting of four floors and a basement, each with a central corridor, has at the east end a 300-MeV. synchrotron with its associated rooms. In the main block are about twenty research rooms, mainly used for small-scale researches in nuclear physics. The unit size is 16ft. by 16 ft., but a few rooms consist of one and a half such units and a few of two units. Techniques rooms, photographic dark-rooms, rooms for mathematical physicists, private rooms, a museum and a library complete the main block.

The synchrotron end of the building consists of a main hall, 54 ft. by 26 ft., for general machine-assembly purposes, this hall containing a 50-ton crane with which the whole of the top section of the synchrotron magnet can be lifted. A large part of the floor of this hall consists of a sliding slab of barytes concrete 2 ft. thick and weighing 120 tons which, when closed, forms the roof of the chamber in which the synchrotron magnet is housed below ground-level. The rest of the building is thus screened effectively from the radiation and noise of the synchrotron. The beam of high-energy radiation passes through a door in the synchrotron chamber into a beam room, 33 ft. by 16 ft., also below ground-level. Immediately above this are two research rooms with slots in the floor, so that the apparatus in the beam room may be watched and manipulated from a safely screened position.

The main synchrotron magnet weighs 120 tons, of which 70 tons is constructed of laminations 0·014 in. in thickness. The diameter of the circular orbit of the electrons during acceleration is 2½ m. The magnet is excited five times a second with a

peak current of 3,300 amp. obtained by the discharge of the condenser block, the total capacity of which is 3,220 μF., the condensers being charged to 8·5 kV. The large rectifier housed in a separate room generates 26 kV., from which a stable voltage supply of 17 kV. is provided for charging condensers. The energy of the accelerated electrons is 300 MeV. at full operation; but at this figure the magnetic field is only 8,000 gauss, and it is expected that the voltage will ultimately be increased to give an energy of more than 400 MeV.

The small extension to the Department of Zoology (architects: Messrs. John Keppie and Henderson and J. L. Gleave) was the first of the new buildings to be completed and has been in use for some years, primarily for teaching and research in the applied branches of the subject. In a teaching laboratory which accommodates some fifty students, practical instruction is provided in agricultural zoology and zoology for veterinary students, as well as in entomology for advanced students. There are staff rooms, research rooms, balance room, a small preparation room, a hot room for insect cultures, and an extension to the departmental library.

The new wing for the Chemistry Department completes a building scheme begun in 1937 (architects: Messrs. T. Harold Hughes and D. S. R. Waugh) and interrupted by the outbreak of the War. The two blocks built then now house the organic chemistry and part of the physical chemistry sections of the Department, with laboratories for medical and dental students; they have also three lecture theatres of varying sizes, a library and a large central store. All three blocks are constructed of ferroconcrete faced with buff-coloured brick, which contrasts with the stone facing of all other University buildings in the vicinity.

The new post-war block contains the inorganic chemistry section of the Department, a large lecture theatre, the sub-department of agricultural chemistry, and two large laboratories for first-year students (science, engineering and veterinary medicine). One of these, a ground-floor laboratory well lit from a glass roof, is flanked on three sides by the remainder of the building, which rises to a height of two more stories. There are also many research rooms, principally for physical chemistry, with a number of special-purpose rooms; for example, for electrochemistry, polarography, microchemistry, etc. A well-appointed conference room and a museum are also included. A number of the larger laboratories are fitted with ventilation units by which warmed and filtered air replaces that lost through the fume cupboards and extraction ducts. Hydrogen sulphide generated in a large apparatus on the roof is led through polythene tubing to the points where it is required in the principal teaching laboratories. The more costly items of equipment recently installed in the Department include a Metropolitan-Vickers mass-spectrometer, a Phillips electron microscope, and a Perkin–Elmer recording infra-red spectrophotometer. The three blocks of the complete building, interconnected by corridors on each of the three levels, make up an impressive Department of Chemistry, probably more extensive than that in any other British university.

The new building for the Department of Surgery (architects: Messrs. T. Harold Hughes and D. S. R. Waugh) is of more modest dimensions. It is a five-story building in Church Street, flanked on one side by the Gardiner Institute of Medicine and on the other by the Tennent Institute of Ophthalmology. A short corridor gives direct access to the surgical wards of the Western Infirmary, where much of the teaching of the Department is carried out. Classes are held in the conference room on the top floor, which is also available for the use of other University departments on the hospital site. The third floor has a museum, a laboratory for clinical investigations and a staff common-room. Below this are more laboratories, for research of biochemical and physiological types. The first floor makes provision for histology, photographic work and medical illustration. On the ground floor is a library, and in the basement an X-ray department and a room for work with radioactive isotopes. Some of the work in progress in the Department is concerned with the study of peptic ulcer, and includes investigations on the epidemiology of ulcer, the physiology of gastric secretion and motility, and the effect of drugs on the stomach.

The Veterinary Hospital (architects: Messrs. Gillespie, Kidd and Coia) is the least advanced of the six new buildings, although part is already in use. It rises on the bank of the River Kelvin in the attractive Garscube estate, about three miles from the main University site. The primary purpose of the Hospital is to provide clinical material for teaching students in the University Veterinary School; much investigation is being carried out also, especially into aspects of livestock management bearing on diseases which constitute an economic problem.

The Hospital comprises buildings for all kinds of domestic animals, and includes the laboratories, operating rooms, X-ray rooms, library and student amenity rooms which make up a modern hospital. The large- and small-animal wings, now in use, run from east to west, parallel to each other, and enclose a yard which is divided into small pens suitable for exercising and retaining animals. The yard is closed on its third side by an east–west block, still under construction, which projects north and south of both the animal wings. As the site slopes from south to north, this north–south wing is a single-story building on the south side, and becomes three-storied on the north side. The main building is a steel-frame building, and an attractive hard-clay brick is being used for the outer fabric.

The entire unit provides accommodation for most types of animals, with facilities for teaching students and carrying out laboratory investigations. There are two lecture theatres, laboratories for biochemistry and physiology, photographic rooms, a clinical pathology laboratory, post-mortem rooms, etc. There is a Large Animal Operating Theatre. This will be used mainly for horses and cattle, and is furnished with a hydraulic operating table capable of taking a horse from the vertical position to the horizontal and of being stabilized at any convenient level for the operator. X-ray equipment will be used both in this operating theatre and in the small-animal operating theatre. X-ray examination of large animals presents peculiar problems, and the designing of a Buckie screen in the floor capable of supporting an animal which may weigh a ton has presented considerable difficulty. Since the former Glasgow Veterinary College was taken over by the University some five or six years ago, its premises have been greatly modified and improved, and the Veterinary School is now provided with good accommodation and equipment. The completion of the new Veterinary Hospital

will mark a further stage in the development in Glasgow of first-class facilities for the training of veterinary practitioners.

Indeed, the new buildings which were inaugurated on March 19 represent for the University as a whole merely a stage of development rather than the fruition of its plans. Much still remains to be done. The temporary buildings for the Department of Chemistry which were in use for half a century are now being demolished, and soon the site will be clear for an extension of the engineering departments. This extension is estimated to cost £600,000 without equipment and, of this, industry has contributed £220,000. A new building has been planned for some of the arts departments, and it is hoped that a start will be made within a very few years. In their turn will come also student residences (only one University has a smaller proportion of its students in halls of residence than has Glasgow), a new University Library and a larger provision for some of the medical and biological departments. When this second stage is complete, the worst of the post-war shortages of accommodation will have been remedied. What the third stage will comprise must be left for future decision. Those who will be responsible for deciding will be greatly helped by the master-plan of University development drawn up a few years ago by the late Sir Frank Mears.

OBITUARIES

Prof. A. B. Dobrowolski

Antoni B. Dobrowolski, Polish meteorologist and hydrologist, whose death has been recently announced, was born in 1872. Like most of his scientifically minded countrymen of that period, he had to turn to the West for his education—in his case to Zurich and Liège. In 1897 Belgium was entering the field of Antarctic exploration, and Henryk Arctowski and Dobrowolski joined the scientific staff of the *Belgica* expedition under the leadership of A. de Gerlache de Gomery with Roald Amundsen as first mate. The ship got stuck in the ice in the west of the Bellinghausen Sea near lat. 70½° S., long. 86° W. at the beginning of the southern winter of 1898. It had perforce to spend the winter there, and so the expedition became the first to take regular meteorological observations and maintain continuous autographic records of pressure and temperature in one part of the Antarctic over a complete year, though not without much hardship and suffering.

Dobrowolski concentrated on the observations of the forms and motions of clouds and on the observation and description of the different forms of snow and ice in the atmosphere. In his treatment of the former he broke new ground in his description of the 'cloud system' and his emphasis on its importance in meteorology. A 'cloud system' covers a large area, and the form of cloud in any part of the system depends on its relative position. Some twenty years after the publication of Dobrowolski's memoir, the significance of these cloud systems, largely owing to their study by French meteorologists, had a profound influence on the work of the International Commission for Synoptic Meteorology and afterwards on the international classification of clouds. Dobrowolski's observations of the motion of clouds were utilized by Simpson in his construction of the pressure distribution at a height of 3,000 m. over the Antarctic; the *Belgica*, the *Gauss*, the South Orkneys and *Erebus* provided a ring of nearly equally spaced observations near lat. 70° S.

F. M. Exner paid a warm tribute to the care and accuracy of Dobrowolski's descriptions of the observed forms of snow and ice crystals when he used them in his revision of the theory of halo phenomena in Pernter–Exner's "Meteorological Optics". Dobrowolski himself maintained that the crystals effective in producing halos were probably the holohedric hexagonal 'columns' and the hemimorphic prisms with an attached plate, because these would tend to float with their axes in one direction, and that simple plates and needles could be practically excluded from consideration as halo formers.

Ice in its manifold forms became, indeed, Dobrowolski's main subject. He wrote a comprehensive treatise, "The Natural History of Ice", published in 1923 under the auspices of the Polish Institute for the Advancement of Science. It was an encyclopædic work of international repute and should have been, as its author desired, in an 'international language'. But it had to be in Polish because the pre-1914 founders of the Institute, desirous of banning the Russian language, had made a rule forbidding all languages other than Polish as the only way, then permissible, of securing their object.

Dobrowolski was director of the Polish National Meteorological Institute during 1924–29. Thereafter, conscious of the dependence of hydrology on meteorology, he sought support at international meetings for his thesis that the meteorological and hydrological services in each country should be united under one head, to secure the close collaboration of which the need was self-evident. He also pressed for the formation of an Association of Cryology in the International Union of Geodesy and Geophysics to replace the Snow and Ice Commission of the Hydrology Association. E. Gold

Colonel L. J. Hudleston

Lawson John Hudleston, who died on April 25, was born on May 8, 1891, and was educated at University College School, and University College, London, where he graduated in 1913. His post-graduate research was soon interrupted by the First World War; holding a Special Reserve Commission, he served with the 1st Middlesex Regiment through the retreat from Mons, was mentioned in dispatches and awarded the Military Cross in 1915. He was transferred to the Ministry of Munitions in 1917 and worked on the synthesis of ammonia until the end of the War; then, as Salters Fellow, he was with Prof. H. Bassett at Reading for a year.

In January 1920 he was appointed lecturer at the University College of Wales, and he settled down in Aberystwyth, marrying Miss Mabyn Thompson, of the Zoology Department, who, with one daughter, survives him; he had been senior lecturer in the Chemistry Department for many years at the time of his death. Persuaded to take command of the Aberystwyth T.A. Battery in 1936, he was in command of the Cardiganshire Field Regiment, R.A., in 1939, and again served throughout the War, during the latter half of it on the staff of the Scientific Adviser to the Army Council. Here his flair and enthusiasm for applying scientific method to novel problems was of great value, and he did important

work on the control of artillery bombardments, and also in getting the scientific approach to such problems appreciated by the fighting units. He was in charge of operational research with the army during its advance through Italy.

Hudleston was the author of "Chemical Affinity" (1928) and numerous papers in the *Journal of the Chemical Society* and the *Transactions of the Faraday Society*. His main interests were in the complex chemistry of fluorides and fluosilicates, and in the theory of the liquid state.

He was also deeply interested in teaching methods, and was held in the highest regard by his students and colleagues. He continued to give whole-hearted service to the community, as well as to the College, after the Second World War; he was chief technical reconnaissance officer in the Cardiganshire Civil Defence organization, and was on a Civil Defence course at the time of his last illness.

C. W. Davies

Dr. Frank Wenner

Dr. Frank Wenner, for many years chief of the section devoted to resistance measurement at the National Bureau of Standards, Washington, died on February 7 at the ripe age of eighty-one. The early years of his scientific career were spent in various teaching posts, first at Knox College where he had graduated in 1895, and afterwards at the University of Wisconsin, Iowa State College, and the University of Pennsylvania. He then joined the staff of the National Bureau of Standards, and for thirty-six years worked on problems centring around the precision measurement of electrical resistance. It was fitting that this work should culminate in a new absolute determination of the ohm. The project was started by Wenner in 1929, and a provisional result was submitted in 1938 to the international committee then engaged in making the transition from the old international unit, based on the standard column of mercury, to the absolute unit. Later, the method was more fully developed by Thomas, Peterson, Cooter and Kotter, who, on publishing the final result in 1949, expressed the opinion that the Wenner method is "the best yet devised". It is undoubtedly one of the very few methods that will survive in the future practice of the national standardizing laboratories.

Wenner was also interested in geophysics and developed an electrical seismometer, for which he was awarded the Wetherill Medal of the Franklin Institute, and a method used by the Iceberg Patrol of the U.S. Coast Guard for measuring the salinity of sea water.

After his retirement from the National Bureau of Standards in 1943, he continued to work as a consultant to various organizations, and he was still active in consulting work at the Bureau when a stroke caused his death.

L. Hartshorn

NEWS and VIEWS

Charles Algernon Parsons (1854–1931)

Sir Charles Algernon Parsons, engineer, inventor and scientist, whose researches revolutionized electric power-station practice and marine propulsion throughout the world, was born in London a century ago on June 13, 1854. He was educated privately and at Trinity College, Dublin, where his father, the distinguished astronomer William Parsons, third Earl of Rosse, had been chancellor. After studying mathematics under E. J. Routh at St. John's College, Cambridge, and passing out as eleventh Wrangler in 1877, he began his engineering training with a four years apprenticeship in the Armstrong Works at Elswick. During 1884–89 he was junior partner in Clarke, Chapman and Co., of Gateshead, where on April 23, 1884, he took out his first patent for the compound steam turbine, which he rendered suitable for the generation of electricity and afterwards for the propulsion of vessels. The *Mauretania* and *Lusitania* were the first great ships propelled by Parsons's turbine. In 1889 he founded at Heaton, near Newcastle upon Tyne, C. A. Parsons and Co., where he manufactured parabolic reflectors for searchlights. His growing interest in optics led him to purchase the Derby Crown Glass Works. His British patents number more than three hundred and include an improved variety of gramophone and a non-skid device for motor tyres. His attempt to make diamonds proved a failure. Many honours came his way, including a K.C.B. in 1911 and the O.M. in 1927. He was elected to the Royal Society in 1898, receiving the Rumford Medal in 1902 and the Copley Medal in 1928, and served as president of the British Association in 1919. He died on a voyage to the West Indies on February 11, 1931. Parsons was a tremendous worker with remarkable powers of concentration, being a keen, critical observer, and all his life he was a firm believer in the importance of research in industry. As a person, he was modest and gentle, and hesitant in manner and speech.

Electrical Engineering in Nottingham: Prof. H. Cotton, M.B.E.

Prof. H. Cotton, who retires from the chair of electrical engineering in the University of Nottingham on September 30 next, studied physics and electrical engineering in the University of Manchester, where he graduated with first-class honours in 1910. He then obtained practical experience at the Municipal Electric Power Station, Hanley, and with the Westinghouse Co. (now Metropolitan-Vickers Electrical Co., Ltd.) at Trafford Park. From the outset he intended to enter the teaching profession, and he was appointed assistant lecturer in physics and electrical engineering at the Technical College, Huddersfield; later he became lecturer at the Technical College, St. Helens. During the First World War he served in France for three years with the Meteorological Section R.E.; he was awarded the M.B.E. (Military Division) and commissioned in the field. Following demobilization in 1919, he was appointed senior lecturer in electrical engineering at the then University College, Nottingham. Here it was necessary to build up a department literally from ground-level. At first he had to bear the whole of the teaching for the external degree course of the University of London, for special courses in mining electrical engineering, for day and evening courses. The work in mining engineering necessitated a special study of the applications of electricity to coal mining, and he published a standard treatise on the subject "Electricity Applied to Mining" in 1929. For some

years his special researches dealt with alternating current machinery, particularly the synchronous induction motor and the rotary converter under transient conditions. He received the M.Sc. degree in 1920 and the D.Sc. degree in 1930, and when the chair of electrical engineering was instituted he was appointed to it. Latterly, his main interest has been in illumination engineering, which appears as an optional subject in the honours courses in electrical engineering. He published a treatise "Electric Discharge Lamps" in 1946; but in spite of a number of more important works his name is most intimately associated with his widely used "Electrical Technology".

Dr. J. E. Parton

Dr. John Edwin Parton, who is to succeed Prof. Cotton, is at present lecturer in the Department of Electrical Engineering, University of Glasgow. Dr. Parton entered the University of Birmingham after a period of industrial experience, and he graduated B.Sc. with first-class honours in 1936 and Ph.D. in 1938. He was then on the staff of the Post Office Engineering Department and Research Station. Dr. Parton served in the Royal Navy during 1939–45, and was demobilized with the rank of lieutenant commander R.N.V.R. He was then appointed as a senior scientific officer in the British Iron and Steel Research Association before becoming a lecturer in the University of Glasgow in 1946. From 1949 to the present time, Dr. Parton has been responsible for teaching and research in the University on electrical machinery. He has published numerous papers on incremental magnetization in iron and on related problems, upon which he is a recognized authority; on the theory of machines and transformers; and on general circuit theory. Dr. Parton is a full member of the Institution of Electrical Engineers, of the Institution of Engineers and Shipbuilders in Scotland and of the American Institute of Radio Engineers; and he is an associate member of the Institution of Mechanical Engineers.

Philosophy at Leeds: Dr. S. E. Toulmin

Dr. S. E. Toulmin, at present lecturer in the philosophy of science in the Faculty of Literæ Humaniores of the University of Oxford, has been appointed to the chair of philosophy in the University of Leeds in succession to Prof. J. W. Harvey, who will retire at the end of the present academic year. Dr. Toulmin is a graduate in mathematics and natural sciences of King's College, Cambridge, taking his B.A. in 1943, and during 1942–45 he served as a junior scientific officer, Ministry of Aircraft Production, being first employed at the Great Malvern radar research and development station and later being attached to the Supreme Headquarters of the Allied Expeditionary Force for technical intelligence work in Germany. From 1947 until 1951 he was a Fellow of King's College, during which period he was awarded the Arnold Gerstenberg Studentship for research in philosophy, and gained his Ph.D. Dr. Toulmin has recently been appointed by the University of Melbourne, under the scheme for Commonwealth university interchange, to take charge of the Department of History and Methods of Science for the academic year 1954–55, and he will not go to Leeds until the beginning of the academic year 1955–56. He has published two books, "The Place of Reason in Ethics" and "The Philosophy of Science: an Introduction", and has also given several series of broadcast talks.

Division of Animal Health and Production, C.S.I.R.O., Australia

Dr. L. B. Bull, chief of the Division of Animal Health and Production of the Commonwealth Scientific and Industrial Research Organization, Australia, will be retiring on June 30, and will be succeeded by Mr. D. A. Gill, at present an assistant chief of the Division and officer-in-charge of the McMaster Animal Health Laboratory, Sydney. Mr. Gill was born in England and graduated as a member of the Royal College of Veterinary Surgeons. In 1925 he went to New Zealand as assistant director of the Veterinary Research Laboratory of the Department of Agriculture at Wallaceville (near Wellington), and then in 1933 he moved to Australia, working for two years at the McMaster Animal Health Laboratory and the University of Sydney as a veterinary pathologist and bacteriologist. After returning to New Zealand as district supervisor in the Department of Agriculture, he went back once more to the McMaster Laboratory in 1937 as officer-in-charge and has continued in that position, except for a period of a year or so during the Second World War when he acted as adviser to the Department of War Organization of Industry on rural matters. Mr. Gill's scientific work has dealt mainly with diseases and pests of sheep. He will be succeeded by Dr. D. F. Stewart as officer-in-charge of the McMaster Laboratory; at the same time, Dr. T. S. Gregory will become officer-in-charge of the Division's Animal Health Laboratory at Parkville (Melbourne).

George Kelley Readership in Oxford in Metallurgy

At a meeting of Congregation held on June 1, the University of Oxford accepted the offer of the Pressed Steel Co., Ltd., to establish a readership in metallurgy, in memory of the late Dr. George Kelley, who was formerly managing director of the Company. Dr. Kelley was an American who graduated at Harvard University, where he spent some years as a lecturer and associate professor. He joined the Pressed Steel Co. in 1931, and took a great interest in industrial and economic matters, and in the well-being of employees under his control. During his years at Oxford he became acquainted with many members of the University, and for his contributions to science and industry he received an honorary M.A. degree in 1943. He played a prominent part in creating the friendly relations existing between the University and the industries of modern Oxford, and it is fitting that his name should be perpetuated in connexion with metallurgy, in which his chief interest lay. The research fellowships established by the Pressed Steel Co. have provided a great stimulus to University research, and the gift of a readership in metallurgy is a further example of the Company's generosity. Research work in metallurgy has been carried out in Oxford for twenty-eight years, and in 1949 metallography was accepted as an official Supplementary Subject. The George Kelley readership marks a further stage in the establishment of metallurgy in the University, and is a great encouragement to those concerned with metallurgical science.

Trans-European Television

A major step in the development of international television was taken on June 6 with the beginning of one month's interchange of television programmes between eight countries—Belgium, Denmark, France,

Germany, Great Britain, Holland, Italy and Switzerland. This is the outcome of an experiment carried out in 1952, when television programmes were exchanged between Paris and London, and followed by the tremendous success of the relaying to certain countries of Western Europe of the 1953 Coronation broadcast of the B.B.C. It should perhaps be explained that the problems involved in disseminating a television programme among European countries are more complicated than those confronting the nation-wide networks of the United States of America. In America, the television system complies with a uniform standard throughout, the language is the same everywhere, and the relay links, whether line or radio, are under the control of one organization —the Bell System.

In Europe, there are four standards of television in operation, there are at least six languages in use, and the communications networks are owned and operated by the individual national administrations. The achievement of programme interchange now undergoing a practical trial is the result of friendly and happy relationships between both the administrations and the technical experts of all the countries concerned. In the course of this interchange, the television signals may have to be converted from the British standard of 405-line definition to either of the French standards 819- and 441-lines, or to that of the 625-line standard adopted in most other European countries. But the problems of conversion from one standard to another and in either direction have now been largely solved following the pioneer work carried out in England and France. The language difficulty is usually resolved by the provision of independent commentators at the scene of the originating programme, thus providing the speech accompaniment appropriate to the various countries in which reception is taking place. On the opening day, June 6, of the present experiments, the afternoon programme originated in Montreux, where a Swiss national fête was in progress; in the evening, viewers enjoyed a visit to Rome and the Vatican City, in the course of which the Pope spoke in five languages commenting on this important event in the history of television.

Antiquity of the Australian Aborigines

An important article in No. 18 of the "Memoirs of the National Museum of Victoria, Melbourne" (1953) is one entitled "Geological Evidence in Western Victoria relative to the Antiquity of the Australian Aborigines" by E. D. Gill, palæontologist at the Museum. The paper occupies sixty-seven pages and is illustrated with sections and photographs and a map. For the past fifty years prehistorians have advanced theories as to the cultural origins of the Australian aborigines and of the Tasmanians. Admittedly their stone industries are primitive in type, especially those of the latter. Suggestions have even been made that we have here to deal with Mousterians who, having arrived somehow in those parts, did not evolve any further. Some workers have long urged that the problem should be taken up energetically locally and sites found where a stratigraphical sequence of the cultures, as shown by the industries they have left behind, could be determined, and where a correlation between the archæological sequence so obtained and the geological record could be made. Much more investigation is still required on both these counts; but in both cases a start has been made. Gill's article deals, of course, with the latter. A short summary indicates the scope of recent advances in knowledge. Three periods of aboriginal occupation of the Lake Colongulac area are known: first, the time of the extinct giant marsupials before the local ash vulcanism, as shown by fossil dingo and a carved bone—the age is thought to be late Pleistocene; second, the Mid-Holocene arid period, as shown by a fossil aborigine in a loess dune; and third, the very recent period. At Pejark Marsh a millstone proves the presence of aborigines as contemporary with the extinct marsupials before the local ash vulcanism. The age here is thought to be late Pleistocene or early Holocene. At Bushfield an axe and bones, etc., show that aborigines were present when the Tower Hill volcano first became active, about a thousand years ago. The work in Australia is not easy, whether for the archæologist or the Quaternary and Holocene geologist. But here is a beginning, and some day we shall have before us the sequence of Stone Age cultures in various parts of Australia and their correlation with the various phases of the late Quaternary and Holocene periods.

Impact

Since criminology is a clinical science, scientific methods of preventing crime must be directed in the first place to the personality of actual—or potential —criminals. Any medical and scientific measures capable of preventing the birth of children with brains malformed, underdeveloped or injured by lesions due to traumatisms or to toxic or infectious agents, and of preventing subjects born normal and healthy from suffering from any type of cerebral lesion can greatly contribute to the prevention of crime. This is the substance of an article by Olaf Kinberg in the spring number of *Impact* (**5**, No. 1. Unesco). Another article, by E. W. Golding, shows that newly established communities in underdeveloped areas may have to be self-supporting, at least in the early stages of development. Local resources of energy may thus assume considerable importance. This fact lends particular interest to the possibilities of such energy sources as wind, solar radiation, peat and waste vegetable matter. Frequently, the energy which could be made available from such sources could meet the needs of a population large enough to undertake the initial stages of development.

Collected Papers of the Rowett Research Institute

The growing importance of agricultural research in Great Britain is reflected in the number and scope of scientific publications emanating from the thirty-odd institutes and units connected with the Agricultural Research Council. One of the largest of these, the Rowett Research Institute, has for some time past made available for limited circulation to sister institutions lists and summaries of each year's collected papers. The papers for 1953 have now been made generally available under the title "Rowett Research Institute: Collected Papers with Summarized Account of Contents" (Vol. 10, pp. 24; obtainable from the Librarian, Rowett Research Institute, Bucksburn, Aberdeen; 2*s*. 6*d*., post paid). In this publication sixty-seven papers scattered over many scientific journals are listed title by title, and the accompanying summary by the director, Dr. D. P. Cuthbertson, is arranged to present the findings in a sequence of topics and development. The publication will be welcomed by many interested in

agricultural progress who find it increasingly difficult to cover the immense scientific literature. It might help them in identifying the separate papers as dealt with in the summary, that runs to thirteen pages, if some indication of their place in the review part could accompany the titles.

The Imperial College of Tropical Agriculture

THE annual report of the Imperial College of Tropical Agriculture, Trinidad, for 1953, by its new principal, Dr. G. A. C. Herklots, contains an account of its staff, administrative organization, teaching and research. Four major research schemes relating to bananas, cacao, sugar and soils are administered by the College, while each of the individual constituent departments pursues appropriate researches. The report (which can be obtained from Trinidad, or from 40 Norfolk Street, London, W.C.2) contains a list of the scientific papers and reports published during the year.

Association of Applied Biologists: Jubilee Conference in London

THE jubilee conference of the Association of Applied Biologists will be held in the Imperial College of Science and Technology, London, S.W.7, during September 13–15, followed by visits to research stations during September 16–17. The conference will be open to non-members of the Association. In the course of a programme of symposia and lectures covering most of the subjects with which the Association has been concerned, many prominent biologists from Britain and overseas will review the past achievements of applied biology and discuss its present trends and future potentialities. The conference will be under the presidency of Prof. W. Brown, emeritus professor of plant pathology in the University of London. The various sessions will be devoted to papers on the following topics: international co-operation in the field of crop protection; insect pests of stored products; plant viruses and virus diseases; plant growth-regulating substances; problems in applied zoology; soil-borne pests and diseases; education and extension services in applied biology; crop protection; forecasting and assessment of plant diseases; and plant nematodes. Three general lectures will be given in the evenings at 5 p.m. as follows: September 13, Prof. E. C. Stakman (emeritus professor of plant pathology, University of Minnesota), on progress and problems in plant pathology; September 14, Prof. V. B. Wigglesworth (Quick professor of biology, University of Cambridge), on the contribution of fundamental research to applied biology; and September 15, Dr. K. W. Neatby (director of Science Service, Department of Agriculture, Canada), on the application of biological research to Canadian agriculture and forestry. In addition there will be a conversazione on September 14 (6.30–10 p.m.), to which all may attend, including those who are not registered members of the Conference. Admission will be by ticket (price 3*s*. 6*d*., including buffet supper), obtainable from the honorary programme secretary before August 31. Correspondence about exhibits should be addressed to the honorary conversazione secretary, Dr. W. F. Jepson, Imperial College Field Station, Silwood Park, Sunninghill, Berks. Those wishing to attend the conference should write to the honorary programme secretary before June 30 (registration fee 10*s*. for members of the Association, and £1 for non-members). The honorary programme secretary is Dr. L. Broadbent, of the Rothamsted Experimental Station, Harpenden, Herts, and the honorary general secretary of the conference is Dr. R. K. S. Wood, of the Botany Department, Imperial College, London, S.W.7.

Wave Research Coastal Engineering: Congress in Grenoble

THE fifth international congress on wave research coastal engineering, organized by the Council on Wave Research of the Engineering Foundation, will be held in Grenoble at the École Nationale Supérieure d'Electrotechnique et d'Hydraulique during September 8–11, under the general chairmanship of Dr. M. O. O'Brien, dean of the College of Engineering, University of California. The programme will consist of papers on the following topics: problems of the protection and utilization of maritime coasts; study of waves and tides; coastal erosion, transport of material in suspension; and the design and construction of marine works. The official languages of the congress will be English and French. Papers may be submitted, not later than June 30, to either the secretary of the congress, Prof. J. W. Johnson, University of California, Berkeley, Calif., or to the local organizing committee at the École Nationale (44–46 Avenue Félix Viallet, Grenoble). The papers will be limited to 20 minutes (maximum of 12,000 words), and those in French must be accompanied by a summary in English not exceeding 600 words.

Summer Schools of Mathematics in Italy

THREE summer schools have been organized this year by the Unione Matematica Italiana and are being held at the Villa Monastero, Varenna (Como), on the following subjects: analytic functions and normed rings; surface area and related topics; and non-linear differential equations. The first school has already started; but the other two are still to come, their dates being August 16–25 and September 15–24, and the closing dates for applications are June 30 and July 31, respectively. The languages used will be English and French; the courses will be limited to twenty-five persons. Application forms and further information can be obtained from the organizing secretary, Prof. Roberto Conti, Istituto Matematico 'U. Dini', Via Alfani 81, Firenze.

Announcements

THE Charter Travelling Scholarship of the Pharmaceutical Society of Great Britain has been awarded for 1954–55 to Mr. Ralph Kohn, a demonstrator in the Pharmacology Department, University of Manchester, to enable him to go to Rome to continue his studies in pharmacology. The Scholarship, which is worth £600, was instituted by the Society to commemorate the centenary of the granting of its Royal Charter in 1843.

THE Institution of Structural Engineers has accepted an offer by the Aluminium Development Association of a research scholarship of £400 a year for two years for research on some aspect of the application of aluminium alloys to structures; the scholarship will be awarded in alternate years. The first award will be made this year, tenable from the beginning of next October, and entries for the scholarship close on July 15. Entry forms and further information can be obtained from the Secretary of the Institution of Structural Engineers, 11 Upper Belgrave Street, London, S.W.1.

SCIENCE AND INDUSTRY IN THE NEXT FIFTY YEARS

FAWLEY FOUNDATION LECTURE OF THE UNIVERSITY OF SOUTHAMPTON

IN the first Fawley Foundation Lecture, entitled "Science and Industry—the Pattern of the Future", delivered in the University of Southampton on May 20, Sir Harold Hartley sought to give a broad picture of changes in the relations of science and industry during the past fifty years and to forecast the way in which they might co-operate to serve the material needs of the world in the next half-century. The great scientific discoveries of around 1900, he said, not only set the stage for the great advances of the next half-century but also contributed to a recognition of the vital part science has to play in industry. Up to 1914, research in Britain was still concentrated in the universities; now great industrial laboratories are contributing not merely to industrial advance but also to advances in fundamental science. Stressing both the magnitude of the increase in expenditure on research since 1900 and the reciprocal influence of science and industry, Sir Harold referred to the contributions which techniques developed in industrial research have made to scientific advance and to the way in which fundamental studies in industrial laboratories have led to important technological advances. He gave as examples the production of such man-made fibres as nylon and 'Terylene', the studies of the influence of traces of impurities on the electrical resistance of semiconductors which have produced the transistor, and those of the crystallization of graphite which have led to the production of nodular cast iron that is tough and can be machined and cast.

Besides this, the past fifty years have witnessed changes in the nature of industry itself, through the mechanization of the production line, with automatic and quality controls, the more scientific processing of raw materials and the introduction of synthetic materials which might replace, or be complementary to, the natural products and used in conjunction with them. These conditions have contributed to the rise of chemical engineering, complementary to the old branches of engineering, and Sir Harold stressed here Britain's need not only for chemical engineers but also for more scientific workers and engineers of all types. He thought that it is a great advantage of a university like Southampton, in close touch with local industries and also with the schools, in which the choice of a career is so often made, that it can recruit and train its students to meet the needs of industry.

Proceeding to forecast the world's needs by A.D. 2000, Sir Harold accepted an increase of 35 per cent in the world's population to 3,250 million on the assumption that Asiatic countries would develop a policy to limit the growth of population. Feeding this population at an adequate standard would require an increase in food production of about two-thirds, or a little more than 1 per cent a year. Sir Harold also assumed a 350 per cent increase in industrial output, with a 125 per cent increase in the consumption of energy and a 300 per cent increase in that of raw materials.

After a rather cursory review of the growing-points of science, in which he stressed the importance of classical physics, geophysics, metal physics and biophysics, the possibilities of radiochemical developments, of studies of the rates and mechanism of chemical reactions and of structural studies of complex organic molecules, and the bearing of genetics and pest control on food supply, Sir Harold discussed the limiting factors likely to determine the pattern of agricultural and industrial development. First, he stressed the importance of water supply and resources, including the treatment of effluents as well as irrigation and, in particular, the probability that in certain large areas multi-purpose water schemes providing power and irrigation as well as flood-control are likely to determine the pattern of development. He anticipated no global shortage of energy by A.D. 2000, though the availability of energy may well determine where development will occur. By A.D. 2000 he anticipated a demand for energy equivalent to 7,500 million tons of coal. At present 18 per cent of energy is consumed as electricity, and he thought that by A.D. 2000 hydroelectric plants and nuclear power stations might well supply the bulk of it. By then liquid fuel requirements might be met partly by oil from shale or coal, petroleum being kept for special purposes. With regard to metals and minerals, while the world is rich in iron and aluminium, the increased industrial production which he forecast would greatly increase our consumption of metals; and, apart from great economy in use and increased recovery of scrap, a formidable task of intensive search for new ore deposits, improved metallurgical methods and conservation would confront us. Sir Harold calculated, moreover, that to provide the nitrogenous fertilizers required by agriculture to feed a population of 3,250 million would involve an extra 25 million tons of steel for constructional purposes and an energy consumption equivalent to 125 million tons of coal.

Such demands come on top of any of those made by the changes in industrial production which he forecast; only intensive agricultural research could reduce the demand and open up new means of supply, possibly by novel methods such as photosynthesis or microbiological processes. Sir Harold placed his main hope of curbing our prodigal use of resources in the work of organizations like the Food and Agriculture Organization of the United Nations and in the plans for technical and economic assistance being worked out under the Colombo Plan, the Point Four plan of the United States and under the United Nations Specialized Agencies. He said little of the educational effort required in the backward countries before we can hope to implement such plans and eliminate the waste of resources where it is most prevalent; and while recognizing the importance of an ecological approach to the use and development of world resources, he set out only the material tasks that confront science and industry in the next fifty years.

HIGH-ENERGY ACCELERATORS, COSMIC RAYS AND ELECTRICAL PROCESSES IN GASES

DUBLIN MEETING OF THE PHYSICAL SOCIETY

THE spring meeting of the Physical Society was held in the Physics Department, University College, Dublin, during March 30–April 1, with the president of the Society, Prof. R. Whiddington, in the chair. This was the first—though, it is to be hoped, not the last—time that the Society has met in Dublin, and the attendance of about one hundred and twenty included about fifty visitors from Great Britain and the Continent. The president of University College and the provost of Trinity College, Dublin, each gave an informal reception which provided opportunities for discussion and social contacts. Three sessions were devoted to topics connected with high-energy accelerators and cosmic rays, and one to excitation and collision processes in gases.

Accelerators

T. G. Pickavance (Harwell) reviewed the problem of accelerating particles, particularly protons, to energies greater than 1 GeV. The synchrocyclotron offers no serious technical difficulties, but the size and cost of the magnet limit its use to energies less than 1 GeV. Neutron and proton intensities of 10^6/cm.^{2}/sec. at some hundreds of MeV. and strong π-meson beams of energy about 200 MeV. are readily obtainable. Above 1 GeV. the synchrotron holds the field for protons, though the necessity of varying the frequency in step with the magnetic field to keep the orbit radius constant makes stability more difficult to attain. The regular operation of the Brookhaven cosmotron at 2·2 GeV. shows the reliability of the device. In present machines the field decreases with radius, so that $dH/dr = -nH/r$, where for stability n lies between 0 and 1. In the strong-focusing or alternating-gradient machine, it is proposed to build a magnet consisting of a large number of sections with $|n| \gg 1$ and positive and negative values in alternate sections. Strong vertical and horizontal focusing forces act in alternate sections. The frequency of oscillations due to scattering and energy-spread at injection is greatly increased and the amplitude is correspondingly reduced. At first it appeared that a vacuum chamber section 2 in. × 2 in. could be used with a magnet radius of 300 ft., but further studies have shown that small errors due to magnet section misalignment and irregularities in the field can in certain circumstances lead to resonant oscillations the amplitude of which builds up catastrophically. At present it appears that it may be possible to use a gap $3\frac{1}{2}$ in. × 4 in. and accelerate protons to 20–30 GeV. at a cost of 20 × 10^6 dollars. Machines for this energy region are being designed at Berkeley and the laboratory for the European Council for Nuclear Research.

The Birmingham proton synchrotron, which is now producing protons of energy near 1 GeV., was described by J. L. Symonds and C. A. Ramm. Symonds described the magnet circuit and gave details of the method used to achieve the correct relation between magnetic field and frequency over the cycle. The rate of rise of the field with time depends only on the generator voltage, nominally 1,100 V., which varies from cycle to cycle. The difference between the actual voltage and a standard voltage of 1,100 is used to correct, from moment to moment, the speed of the rotating condenser which varies the frequency of the radio-frequency oscillator in step with the increasing magnetic field. Ramm described the injection system and gave details of a very ingenious device for plotting trajectories in the synchrotron field.

J. R. Richardson, describing the Berkeley accelerators, announced that the bevatron has produced protons of energy 5 GeV. It is proposed in the near future to modify the synchrocyclotron (340 MeV.) to accelerate protons to 730 MeV. by increasing the field from 15 to 22 kilogauss. The rotating capacitor used to vary the frequency will be replaced by a vibrating reed system. J. R. Holt described the present stage of development of the Liverpool cyclotron, which is expected to give 400-MeV. protons, and Dr. S. E. Barden gave an informal talk on the Glasgow 300-MeV. electron synchrotron which at its present stage of development accelerates electrons to 200 MeV. Max Hoyaux (Charleroi) discussed the problem of radial focusing and the variation of optimum frequency with energy in very long heavy-particle linear accelerators.

Cosmic Radiation

The use of stacks of stripped emulsions is providing much new information about heavy unstable particles. D. H. Perkins (Bristol) described the methods of search. τ-, θ^0- and Λ^0-particles can be found by tracing π-mesons from rest to their point of origin in the stack. Nine two-prong stars appear to be produced by the decay of Λ^0-particles to a proton and a π-meson with a Q-value of 37·0 ± 0·3 MeV. Two τ-mesons have also been found.

The tracing through the stack of particles from stars containing two or more shower particles may give K-mesons and charged hyperons. This work has yielded one charged hyperon and seven K-particles with mass in the neighbourhood of 1,000 m_e which come to rest and decay. Protons with β in the range of 0·5–0·85 in general do not stop in the emulsion, but particles with velocities in this range can be identified from scattering and blob counting. One charged hyperon decaying in flight and two particles of mass 1,000 m_e have been noted. Earlier work of Daniel and Perkins seemed to show the emission from stars of particles with mass about 1,400, and at the conference last year in Bagnères de Bigorre the discrepancy between this mass value and that of the K-particle was pointed out. Further work has failed to show the existence of systematic error in the measurements, and the problem of the existence of this set of mass values between the K and proton mass is still unresolved.

Up to now, very few negative K-particles have been observed to come to rest and interact. J. V. Major described two interactions of K-particles at rest found by the Manchester group. In one case a π-meson and an evaporation proton are observed, and in the second case there are three short-range secondaries.

D. J. Hughes (Brookhaven) announced that the cosmotron group, continuing its work with the diffusion cloud chamber on pair production of heavy unstable particles, has observed three additional examples of Λ^0-particles which must have been

accompanied by θ^0-particles that did not decay in the chamber and one further example of the simultaneous production of a Λ^- and K^+-particle in the collision of a π^--meson with a proton. Dr. Hughes also discussed the Brookhaven results on the total cross-section for the scattering of $\pi^\pm$-mesons by protons. The π^- cross-section shows peaks at about 200 MeV. and 1 GeV., and the π^+ cross-section shows only the peak at 200 MeV.

K. H. Barker described an event found by the group from the Imperial College of Science and Technology, London, in which a heavy negative particle interacts in lead to give a Λ^0-particle. Momentum and ionization measurements suggest that the primary particle is probably a heavy meson. He also discussed the problem of improving the accuracy of the momentum-ionization method of measuring mass in cloud chambers. O'Ceallaigh (Dublin) described improvements in the gap-range method of mass measurement in emulsions and the optimum development conditions for discriminating between the masses of particles coming to rest in emulsions. J. McConnell (Maynooth) summarized his calculations on the probability of a negative proton being present in a shower caused by a nucleon–nucleus collision, the energy of the incoming nucleon being greater than 7 GeV. If the nuclear force coupling is pseudoscalar, the probability is about 2 per cent for a nitrogen and 4 per cent for a silver or bromine nucleus. If, as seems more likely from meson–nucleon scattering experiments, the coupling is pseudovector, the order of magnitude of the probability is about one in a thousand.

B. G. Owen described work in progress at Manchester on the energy spectrum of μ-mesons at sea-level. The differential spectrum follows a law $dN = E^{-\gamma}\,dE$, in which γ varies with energy from 1·7 at $0{\cdot}6 \times 10^{10}$ eV. to 3·0 at 5×10^{10} eV. The existence of a short-range non-electromagnetic interaction between μ-mesons and nucleons has been inferred from the supposed existence of an anomalous non-Coulomb scattering of μ-mesons. J. McDiarmid (Manchester) described work at a water-equivalent depth of 26 m. with a multi-plate cloud chamber. A comparison of the results with the theories of Molière and Olbert suggests that no appreciable anomalies in the scattering exist.

Two papers on extensive air showers were contributed by the Harwell group. J. V. Jelley described some very interesting work on light pulses associated with showers. The light is found to be polarized and is undoubtedly Čerenkov radiation, presumably from the cores of the showers. The radiation is highly directional, and this property has been used to search for localized sources of cosmic rays. There is no correlation between the direction of the radiation and point radio-sources in the galaxy. W. Galbraith described the Harwell extensive shower-set (Cranshaw and Galbraith) which detects showers of energy 10^{16}–10^{17} eV. The primary particle spectrum seems to obey an integral power law $N(>E) \sim E^{-\gamma}$ up to 10^{17} eV. with γ about 1·7. No obvious marked variation with solar or sidereal time has been found, though there is some evidence for a possible sidereal variation at higher energies.

The polarization of scattered protons observed at Rochester, N.Y., gives information on nuclear tensor or spin-orbit forces. T. C. Randle gave information about the Harwell experiments of Dickson and Salter in which protons scattered by carbon at 20° are scattered a second time by carbon at 20°. There is a considerable difference between the number of protons to the right and the left in the second scattering. The asymmetry is most marked at higher energies of about 140 MeV., and the maximum polarization observed for protons elastically scattered from carbon is between 75 and 100 per cent. The Brookhaven high-speed chopper for neutron spectroscopy by the time-of-flight method was described by D. J. Hughes. The neutron detection is by boron trifluoride counters over a path of 20 m. in helium, and a hundred separate velocities are recorded simultaneously. The high resolution makes possible a very detailed and accurate study of the radiation and particle widths of levels and of level densities for comparison with the predictions of various nuclear models.

To conclude this part of the meeting, J. L. Synge (Dublin) discussed certain considerations relating to the relativistic theory of the collisions of particles which possess angular momentum.

Excitation and Collision Phenomena

A group of papers, mainly on excitation and collision processes, were contributed from the Departments of Applied Mathematics (D. R. Bates) and Physics (K. G. Emeléus) of The Queen's University, Belfast. In the opening paper, A. Dalgarno gave a general review of the phenomenon of autoionization, the radiationless transition into the continuum which can occur when an energy-level of an atom is above the lowest ionization potential. This process broadens the corresponding spectrum lines, and widths as great as 500 $cm.^{-1}$ occur. Great interest is attached to doubly excited levels of helium and beryllium, and Dr. Dalgarno stressed the need for further experimental work.

Two papers dealt with the application of the Landau–Zener formula for transition probabilities. The first paper (D. R. Bates and B. L. Moiseiwitsch) dealt with charge transfer processes, $H + X^{++} \rightarrow H^+ + X^+$ (X = Be, Si or Mg), arising from the pseudo-crossing of the potential energy curves of the initial and final systems. The cross-sections associated with these processes have been calculated for a wide range of impact energies. The second paper (D. R. Bates and J. T. Lewis) described the modification of the formula for application in the case of degeneracy. The degeneracy may greatly alter the dependence of the probability on the radial component of the velocity of relative motion at the crossing-point.

U. Öpik discussed the Layzer approximation for the treatment of collisions of electrons with atoms based on first-order perturbation theory. Results for the excitation of the 2^2S level of hydrogen and the $1s2s^1S$ and $1s2s^3S$ level of helium were compared with those obtained by other methods. The agreement seems sufficiently promising to justify further work with the view of establishing means of obtaining cross-sections for slow incident electrons correct to within a factor of two. The application of the Born approximation to the study of rotational and vibrational excitation of molecular hydrogen by electron impact was treated by T. R. Carson. The choice of the interaction potential has a marked influence on the vibrational excitation function in the low-energy region.

D. T. Stewart described experimental techniques of determining excitation functions of nitrogen band spectra using electron beam sources. A photomulti-

plier in conjunction with a tuned a.c. amplifier seems to give more accurate results than photographic photometry. The excitation functions of N_2^+ have broad maxima for the Meinel bands at electron energies of 90 eV. and for the first negative bands at 95 eV.

In a discussion of the relation of nitrogen atoms to active nitrogen, P. Gribbon pointed out that uncertainty still exists about many features of the production and persistence of nitrogen atoms in discharge tubes and the upper atmosphere. W. Hayes (Dublin) discussed the interpretation of the high-multiplicity bands of the manganese halides in the near ultra-violet and gave an account of new work on these spectra which has resulted in the discovery of many new band systems.

T. E. NEVIN

SCIENTIFIC COUNCIL FOR AFRICA SOUTH OF THE SAHARA

REPORT FOR THE YEAR 1952–53

THE second report of the Scientific Council for Africa South of the Sahara, which covers the year July 1952–June 1953*, refers to the marked tendency for certain major problems to be considered sub-regionally. There are now soil problem committees meeting in three out of four sub-regions, and this pattern is expected to be followed as collaboration in other subjects develops. Although the mode of operation of the Council has become better defined, the establishment of the secretariat was only completed towards the end of 1952, and in some directions scientific collaboration has made slow progress.

At the third session of the Council during August 11–14, 1952, at Bukavu (Costermansville), Belgian Congo, special attention was paid to maps and survey, geology, meteorology, zoology, fisheries and social studies. A specialist meeting on fauna research was held during October 1952 in Nairobi, and an inter-African conference on fauna and flora, convened at Bukavu for October 1953, was scheduled to review the international convention of 1933 in the light of subsequent experience and to consider whether any modifications in policy concerning wild-life are required. A meeting of specialists in planning social research was held at Makerere College, Uganda, during February–March 1953, which listed a number of joint projects and statements on organizations and institutes engaged in social research in Africa and on work in progress which are being prepared for the participating countries or sub-regions. A symposium on African hydrobiology and inland fisheries was held at Entebbe, Uganda, in October 1952, and a report including summaries of the papers and discussions is appearing as C.S.A. Publication No. 6.

Much effort has been devoted to the preparation of a comprehensive list of maps available for the whole region, and this list, including special subject maps as well as topographical maps, has been issued as C.S.A. Publication No. 4. A meeting to discuss the possibility of greater co-ordination, particularly in special subject maps, was to be convened after the fourth session of the Council in August 1953. Good progress is reported in the co-ordination of geological work in the various sub-regions, and full agreement is anticipated on the appointment of a geological scientific correspondent to maintain touch with and assist the many geological surveys and other organizations for geological investigation in the region. A project has been developed for the preparation of a climatological atlas of Africa, but it is expected that two or three years will be required to collect and analyse all the data available on rainfall, temperature and winds, etc., and prepare the series of maps. The "Flore du Congo Belge" and the "Flora of East Africa" were enlarged during the year by further publications, and information has been collected for a comprehensive list of taxonomists who are engaged on African problems in the many different groups of plants and animals. During the year particulars of two hundred and forty scientific and technical libraries in Africa south of the Sahara were published in C.S.A. Publication No. 3, and particulars are being collected of the holdings of periodical literature in the libraries of the sub-regions. Publication of a list of these holdings is to be followed ultimately by the preparation of comprehensive catalogues, at least for the major libraries. Steps have also been taken towards the preparation of a directory of scientific institutes and organizations in the region.

* Scientific Council for Africa South of the Sahara. Publication No. 5: Second Report—July 1952 to June 1953. Pp. 46. (Bukavu, Congo Belge: Scientific Council for Africa South of the Sahara, 1953.)

CACAO RESEARCH DURING 1952–53

THE report of the West African Cacao Research Institute for 1952–53* is brief, giving little more than notes on the many lines of investigation that are being followed. Studies of the swollen shoot virus are, as usual, prominent, and many of them are systematic observations that have been going on for several years. These include the recording of symptoms produced in young seedlings by new virus strains (which are still being found) and cross-protection tests with the view of classification. The search for new alternative hosts goes on, and it is hoped that eventually all species related to *Theobroma cacao* occurring in the Gold Coast will be tested for susceptibility. Transmission trials with possible new vectors are linked up, on the entomological side, with equally systematic examination of mealybugs and their parasites and predators, and with extensive screening of systemic insecticides for control of vectors.

The chemistry section is attempting, by paper chromatography, to discover differences in composition between healthy and diseased tissues, analysing also the secretions of mealybugs that have fed upon healthy and diseased tissues. The botany section has cultured cambial tissues *in vitro* from healthy and diseased trees, so far without finding any differences in growth pattern or histology. Other diseases and pests of the cacao tree are receiving attention, especially capsids and the black pod disease caused by *Phytophthora palmivora* Butler. It is noted that dusting against capsids with DDT seems to have no important deleterious effect on pollinating insects. One dusting machine among a number tried merits further attention. Long-term

* West African Cacao Research Institute, Tafo, Gold Coast: Annual Report April 1952 to March 1953. Pp. 39. (Published on behalf of the Institute by the Crown Agents for the Colonies, London, 1953.) 5s.

breeding and genetical studies are mentioned, among which the results of extensive interspecific crossing in *Theobroma* will be awaited with particular interest.

A report* from the Imperial College of Tropical Agriculture, Trinidad, supplements that for the seven years 1945–51 which was reviewed in *Nature* (**173**, 115; 1954). Much of the work recorded is concerned with the nutrition of the cacao tree. One paper continues (from the earlier report) the description of an experiment comparing the reactions of young cacao to different combinations of shade and manurial treatment. Others deal with mineral injections, rapid chemical tissue tests, leaf sampling, the treatmen of iron chlorosis with the iron complex of ethylene diaminetetraacetic acid, and marginal leaf scorch. Biochemical studies are progressing, with particular reference to establishing a technique for the satisfactory fermentation of small samples. A note on the conditions of fermentation will be of special interest to users of raw cacao. The report also includes useful notes on minor insect pests of cacao in Trinidad.

E. E. CHEESMAN

* Report on Cacao Research 1952. Pp. 71. (Imperial College of Tropical Agriculture, St. Augustine, Trinidad, B.W.I., 1953.) 8s.

THE POLECAT IN WALES

LIKE that of several other British mammals, the distribution of the polecat has not yet been fully investigated. Being a creature of the night and mainly haunting sparsely inhabited uplands or the wilder parts of the lowlands, it is a difficult and often inaccessible subject for study. There is the further complication that ferrets, which are apparently not descended from the British polecat but from a North African species, have for many centuries been escaping and crossing with wild polecats so that perhaps nowhere in Britain can the polecat be claimed to be a 'pure' species. It is, according to William Condry (*Oryx*, 2, No. 4; March 1954), only in Wales and the Marches, probably in Devon and Cornwall, and possibly in the Lake District, that polecats can safely be said to be genuinely wild. Mid-Wales is undoubtedly their stronghold. The animal is really common in the counties of Cardigan, Merioneth, west Montgomery, Radnor and Brecon.

A remarkable feature of the polecat is the variety of habitats in which it can flourish. Polecats are found in Wales from the coast right up into the hills, and are as much at home in sand-dunes and sea-cliffs as they are about lowland farms, wild wooded gorges, or the margin of bogs. Rabbit-meat is their staple food; but some live quite independently of it, for there are polecats but no rabbits in some of the moorland plantations of the Forestry Commission near the head of the Severn. In such places voles are perhaps their commonest prey.

Polecats seem to be most numerous in the rough, semi-upland, marginal farm country of which there is so much in mid-Wales and which is so often overrun with rabbits. For it is in ground honeycombed with warrens that polecats thrive best, where they find plenty of food and endless underground galleries in which to lie up in the daytime and where they can have their litters in comparative safety. Although they are often found very close to farms they very rarely attack poultry, despite the reputation as chicken killers which they have had since medieval times.

The polecat's future is, to a large extent, tied up with that of the rabbit; for although polecats can live independently of rabbits, they thrive best where rabbits are plentiful. At present the polecat is probably still increasing and, where rabbit trapping is on a small scale, even extending its range.

CHEMICAL PRIMARY PROCESSES IN THE ACTION OF IONIZING RADIATIONS ON WATER: EVIDENCE FROM EXPERIMENTS WITH HEAVY WATER

By PATRICK KELLY, DR. TYSON RIGG and DR. JOSEPH WEISS

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IT is well known that the energy loss of fast particles proceeds through processes of ionization and excitation. On this basis, it was suggested[1] that the most important chemical primary process in the action of the ionizing radiations on water can be represented by the net reaction:

$$H_2O \rightsquigarrow H + OH, \qquad (1.1)$$

leading to the formation of H atoms and OH radicals. Afterwards, it was pointed out by Allen[2] that there appeared to be an additional relatively small decomposition of the water molecules leading somehow directly to the formation of molecular hydrogen (and of an equimolecular amount of hydrogen peroxide). It was assumed that this also proceeds via the splitting of water molecules, according to equation (1.1), and that formation of this molecular hydrogen was due to preferential recombination of some of the hydrogen atoms in 'hot spots' along the tracks of the ionizing radiations. However, a number of experimental facts were difficult to reconcile with such a mechanism, based as it is on the intermediate formation of hydrogen atoms.

It was therefore proposed more recently[3] that this 'molecular yield' might be due to the direct interaction of excited water molecules (H_2O^*), according to:

$$\begin{matrix} HOH^* \\ HOH^* \end{matrix} \longrightarrow \begin{matrix} H \\ | \\ H \end{matrix} + \begin{matrix} OH \\ | \\ OH \end{matrix} \quad (\text{rate constant } k_{2\cdot 1}), \qquad (2.1)$$

and it was suggested that these processes could take place in the more densely populated clusters along the tracks created by the fast particles, where excited molecules should be formed sufficiently close to each other to enable a bimolecular interaction to occur with some probability; this would also be consistent with the relatively very low value of the 'molecular' yield.

The problem has been to design an experiment which would allow one to distinguish between: (i) the hydrogen gas formed by the recombination of hydrogen atoms, and (ii) the hydrogen molecules formed directly in a single elementary process.

It has now been found that such information can be derived from a study of the isotopic composition of the hydrogen gas which is given off from water, enriched with heavy hydrogen, under the influence of ionizing radiations.

Formation of molecular hydrogen from the atoms. In the case of ionizing radiations, primary formation of hydrogen and deuterium atoms should, in addition to equation (1.1), proceed thus:

$$HDO \text{ —}\rightsquigarrow H + OD \qquad (1.2)$$

$$HDO \text{ —}\rightsquigarrow D + OH \qquad (1.3)$$

(that is, for sufficiently low deuterium content, when the reactions of D_2O can be neglected). On the other hand, it is known from independent evidence[4] that hydrogen and deuterium atoms may, in general, undergo a relatively rapid exchange with water, under which conditions the hydrogen given off should correspond, more or less closely, to the following equilibrium:

$$H_2O + HD \rightleftharpoons HDO + H_2 \qquad (3)$$
$$\text{(equilibrium constant } K_3\text{)}$$

For complete equilibrium conditions, the separation factor (s) defined in the usual way[5] is given (for sufficiently low deuterium content) by the equilibrium constant (K_3) of reaction (3), namely:

$$s = \frac{\left[\frac{(H)}{(D)}\right]_{gas}}{\left[\frac{(H)}{(D)}\right]_{water}} = \frac{\left[\frac{(H_2)}{(HD)}\right]_{gas}}{\left[\frac{(H_2O)}{(HDO)}\right]_{water}} \simeq \frac{[HDO][H_2]}{[H_2O][HD]} = K_3 \qquad (= 3{\cdot}8 \text{ at } 25^\circ \text{ C.}^6) \quad (4)$$

In the case of the photochemical formation of hydrogen or deuterium atoms from aqueous ferrous sulphate solutions irradiated with ultra-violet light[7], we have been able to confirm, on the whole, the previous findings of Farkas and Farkas[4], and separation factors of about 4·1–4·3, corresponding approximately to the equilibrium (3), have been obtained in the course of the present work.

When dilute aqueous solutions of ferrous sulphate are irradiated by ionizing radiations (gamma-rays, X-rays), it has been shown previously that the primarily formed OH radicals (equation 1) react according to[1]: $Fe^{2+} + OH \rightarrow Fe^{3+} + OH^-$, whereas the hydrogen atoms, at relatively high pH, react mainly according to: $Fe^{III} + H \rightarrow Fe^{II} + H^+$ and $2H \rightarrow H_2$. Therefore, the hydrogen gas evolved under these conditions from irradiated ferrous sulphate solutions should again correspond more or less closely to the equilibrium composition according to equation (3). Some of the results obtained are given in Table 1 (Exp. 1 and 2), from which it will be seen that the separation factors in the radiation chemistry of aqueous ferrous sulphate solutions are somewhat lower than those obtained in the corresponding photochemical experiments. This could be due, for example, to a difference in the spatial distribution of the primarily formed hydrogen atoms. However, as discussed above, in the case of ionizing radiations a certain amount of the hydrogen gas produced is due to the 'molecular' process, and it seemed likely that the difference in the separation factors is, at least partly, due to a contribution from this process.

Table 1. Separation Factors for Hydrogen Evolution from some Aqueous Solutions irradiated with X-rays of 200 kV.* Solutions contained approximately 0·9 mole per cent of deuterium

Exp. No.	System irradiated	Separation factor† (s)
1	1×10^{-3} *M* Ferrous sulphate in 0·8 *N* sulphuric acid de-aerated	3·45
2	1×10^{-3} *M* Ferrous sulphate in 0·025 *N* sulphuric acid de-aerated	3·60
3	1×10^{-3} *M* Ferrous sulphate in 0·8 *N* sulphuric acid saturated with oxygen (1 atm.)	1·90
4	2×10^{-3} *M* ceric ammonium sulphate in 0·8 *N* sulphuric acid de-aerated	1·94

* Conditions of irradiation as described in ref. 1 *b*.
† The total error in these measurements is estimated to be about ± 3 per cent.
The isotopic analysis was carried out by means of a mass spectrometer (Metropolitan-Vickers *M.S.* 2).

Direct formation of molecular hydrogen. The object of the following experiments was to 'isolate' the hydrogen formed in the 'molecular yield' process in order to study its isotopic composition in the 'undiluted' state. It should be possible to do this by adding to the water suitable substances (acceptors) which are known to react rapidly with hydrogen atoms (and deuterium atoms), and thus the recombination of these atoms to give molecular hydrogen should be prevented. For this purpose irradiations were carried out with dilute aqueous solutions of, for example, molecular oxygen or ceric salts, as it is known that the reactions $O_2 + H \rightarrow HO_2$ and $Ce^{IV} + H \rightarrow Ce^{III} + H^+$ are very efficient processes.

On the basis of the interaction of excited water molecules, the following reactions in addition to reaction (2.1) have to be considered, when the water contains only a relatively small percentage of deuterium:

$$HDO^* + H_2O^* \rightarrow H_2 + HDO_2 \qquad (2.2)$$
$$\text{(rate constant } k_{2.2}\text{)}$$

$$HDO^* + H_2O^* \rightarrow HD + H_2O_2 \qquad (2.3)$$
$$\text{(rate constant } k_{2.3}\text{)}$$

From these equations one can easily derive the following simple expression (for low deuterium content) for the separation factor (s), defined again as in equation (4):

$$s = \frac{2k_{2.1} + k_{2.3}([HDO]/[H_2O])}{k_{2.3}} \simeq \frac{2k_{2.1}}{k_{2.3}} \qquad (5)$$

The factor of 2 arises because the H_2O molecule, as distinct from HDO, reacts in the same way at both ends.

Some experimental results relating to 'molecular yield' hydrogen are given in Table 1 (Exp. 3 and 4). From these it appears that the separation factors, in cases where one is dealing with the undiluted 'molecular yield' hydrogen, have values of approximately 2. A separation factor of $s \simeq 2$ would follow immediately from the above equation (5), for:

$$k_{2.1} \simeq k_{2.3}. \qquad (6)$$

This assumption about the rate constants seems reasonable, since it is very likely that the reactions between electronically excited water molecules (equations (2.1) and (2.3)) will require no energy of activation, so that differences in the zero-point energies will be practically without effect. Likewise, in view of the similarity of the reacting molecules, the non-exponential factors should also be of the same magnitude. Furthermore, the second term in the numerator of equation (5) is always negligible under the present conditions where $[HDO] \ll [H_2O]$ and in view of the similarity of reactions (2.1) and (2.2). Thus, the mechanism proposed above immediately explains the relatively low separation factor of about 2, which has been obtained for the 'molecular yield' hydrogen. On the other hand, separation factors

greater than 2 are to be expected when the hydrogen given off is due partly to the recombination of atoms and partly to the interaction of excited water molecules.

It would seem, therefore, that the study of the isotopic composition of the hydrogen gas, given off under the influence of ionizing radiation from aqueous solutions enriched with heavy water, is capable of furnishing some direct evidence about the mechanism of the primary processes in the radiation chemistry of water.

A full account of this work will be published elsewhere.

[1] (*a*) Weiss, *Nature*, **153**, 748 (1944). (*b*) Rigg, Stein and Weiss, *Proc. Roy. Soc.*, A, **211**, 375 (1952). (*c*) Weiss, "Ann. Rev. Phys. Chem.", **4**, 143 (1953).

[2] (*a*) Allen, *J. Phys. Chem.*, **52**, 479 (1948). (*b*) Allen and Johnson, *J. Amer. Chem. Soc.*, **74**, 4147 (1952).

[3] Weiss, International Congress of Pure and Applied Chemistry, Stockholm (1953).

[4] Farkas and Farkas, *Trans. Farad. Soc.*, **34**, 1120 (1938).

[5] Urey and Teal, *Rev. Mod. Phys.*, **7**, 34 (1935).

[6] cf. Kirshenbaum, "Physical Properties and Analysis of Heavy Water", 42 ff. (McGraw-Hill, 1951).

[7] Rigg and Weiss, *J. Chem. Phys.*, **20**, 1194 (1952).

A NEW GLYCERALDEHYDE PHOSPHATE DEHYDROGENASE FROM PHOTOSYNTHETIC TISSUES

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An investigation of the glycolytic enzymes in photosynthetic tissues yielded evidence for the existence of a new TPN-specific enzyme which catalyses the oxidation of glyceraldehyde-3-phosphate without the addition of either inorganic phosphate or arsenate[1]. This communication reports the isolation of the new enzyme accomplished during the fractionation of the triose phosphate dehydrogenase system of green leaves. Three fractions were separated: *A*, the new enzyme*; *B*, a TPN-activated, phosphate- or arsenate-dependent glyceraldehyde phosphate dehydrogenase; *C*, a DPN-specific, phosphate- or arsenate-dependent glyceraldehyde phosphate dehydrogenase. The enzyme in fraction *C* is analogous to the 'classical' glyceraldehyde phosphate dehydrogenase of yeast[2] and muscle[3] and catalyses the reaction:

glyceraldehyde-3-phosphate + orthophosphate + $DPN^+ \rightleftharpoons$ glyceric acid 1,3 diphosphate + DPNH + H^+ (1)

(DPNH = reduced form of diphosphopyridine nucleotide; DPN^+ = oxidized form of diphosphopyridine nucleotide (coenzyme I))

The oxidation of glyceraldehyde-3-phosphate by enzyme extracts from plant tissues shows varied pyridine nucleotide dependence. Enzyme extracts from non-green tissues such as seeds[4,5] and roots[5,6] are DPN-specific, as is the crystalline enzyme from yeast[2] and muscle[3]. On the other hand, extracts from green tissues were found to catalyse the oxidation of glyceraldehyde-3-phosphate with either di- or tri-phosphopyridine nucleotide[6-8] as represented by reaction (1) or (2):

glyceraldehyde-3-phosphate + orthophosphate + $TPN^+ \rightleftharpoons$ glyceric acid 1,3 phosphate + TPNH + H^+ (2)

(TPN^+ = oxidized form of triphosphopyridine nucleotide (coenzyme II); TPNH = reduced form of triphosphopyridine nucleotide).

A comparison of the DPN- and TPN-linked oxidation of glyceraldehyde-3-phosphate by extracts from green leaves revealed a divergent response to inorganic phosphate. In one series of experiments[7] with an unpurified enzyme preparation, the oxidation of the triose phosphate was faster and more complete at *p*H 7·3 and 0·025 *M* phosphate with tri- than with di-phosphopyridine nucleotide. In other experiments with partly purified enzyme preparations it was found[8] that the oxidation in the TPN-linked system, unlike that in the DPN-system, proceeded readily at *p*H 8·5 even with low phosphate concentrations (0·010 *M* and 0·001 *M*). The reactions proceeded beyond the expected equilibrium states and the reduction of triphosphopyridine nucleotide continued for a long time*. Further study of this anomalous phosphate effect led to the unexpected results illustrated in Fig. 1. With tri- but not with di-phosphopyridine nucleotide, the oxidation of glyceraldehyde-3-phosphate by a dialysed enzyme extract proceeded in the absence of added phosphate (or arsenate). These results, repeated many times with different enzyme preparations, indicated the presence of a third enzyme species, since the oxidation

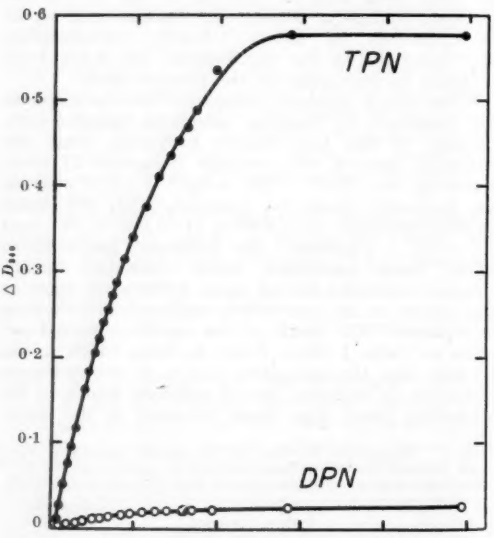

Fig. 1. Oxidation of glyceraldehyde-3-phosphate by dialysed leaf extracts without the addition of either inorganic phosphate or arsenate. The reaction mixtures each contained 0·2 ml. of the enzyme preparation (0·9 mgm. protein) and the following in micromoles: D-glyceraldehyde-3-phosphate, 0·26 (added as D-L-glyceraldehyde-1-bromide phosphoric acid dioxane compound); tris (hydroxymethyl) amino methane buffer, 90; cystein hydrochloride, 9; di- or tri-phosphopyridine nucleotide, 0·3; sodium fluoride, 10; and water to a final volume of 3·0 ml. Final *p*H 8·5; reaction was started by adding glyceraldehyde-3-phosphate. Reference cuvettes contained all the ingredients except the pyridine nucleotide, d = 10 mm.

* *Note added in proof.* Since this manuscript was submitted for publication a ninety-fold purification of the new enzyme has been attained.

of glyceraldehyde-3-phosphate in the presence of *catalytic* amounts of either the 'classical' DPN-dependent enzyme[2,3] or the previously reported TPN-dependent enzyme from green tissues[6–8] will not proceed without added phosphate or arsenate.

A direct demonstration of three distinct glyceraldehyde phosphate dehydrogenases in green leaves was provided by the isolation of the individual enzyme fractions (*A*, *B* and *C* above) from a leaf extract which initially possessed all three activities. The two TPN-dependent enzymes (fractions *A* and *B*) were distinguished by their different response to varying phosphate concentrations. With fraction *B*, the concentration of TPNH at equilibrium is a direct function of phosphate concentration, as would be expected from equation 2. The new enzyme (fraction *A*), however, was found to be inhibited by inorganic phosphate (Fig. 2). This indicated that in the oxidation of glyceraldehyde-3-phosphate by the new enzyme, inorganic phosphate does not participate as it does in reactions (1) and (2). In addition to the reduced triphosphopyridine nucleotide, which was measured spectrophotometrically, the other product of the oxidation reaction catalysed by the new enzyme was identified as glyceric acid 3-phosphate by means of paper chromatography[9] and by changes in hydrolysable phosphate[10]. The reaction catalysed by the new enzyme can therefore be represented by equation (3):

$$\text{glyceraldehyde-3-phosphate} + \text{TPN}^+ + \text{HOH} \rightarrow \text{glyceric acid 3-phosphate} + \text{TPNH} + \text{H}^+ \quad (3)$$

This reaction, which is analogous to the well-known irreversible reaction in the presence of arsenate, results in loss of energy of oxidation of triose phosphate. It is interesting to speculate that the oxidation catalysed by the new enzyme proceeds as represented in reaction (3) only in the absence of a natural phosphoglyceryl acceptor. This postulated acceptor which should conserve oxidation energy as 'configurational' energy cannot be inorganic phosphate as it is in the reactions catalysed by the 'classical' glyceraldehyde-3-phosphate dehydrogenase[11–13] and by fractions *B* and *C*; it might be a sulphydryl compound analogous to coenzyme *A*. The intervention of such an acceptor could provide the system with an energy-conserving mechanism alternative to the phosphate-transferring system (phosphoglyceryl kinase + adenosine diphosphate) of the classical glyceraldehyde-3-phosphate dehydrogenase. These theoretical possibilities are being investigated at present.

The appearance and disappearance of TPN-dependence of the glyceraldehyde phosphate dehydrogenase system during the life-cycle of green plants is of special interest. It was demonstrated[5] that the TPN-dependent activity was induced in the emerging shoot by light and disappeared in the newly formed seed. Light seems to be effective only in the presence of chlorophyll.

It was found in preliminary experiments that illuminated cultures of *Chlorella variegata* grown in an organic medium possessed only the conventional DPN-dependent glyceraldehyde phosphate dehydrogenase. This alga when grown in an organic medium fails to synthesize chlorophyll even under continuous illumination[14]. There appears to be an association between photosynthesis and the emergence of a TPN-dependent glyceraldehyde phosphate dehydrogenase system. It is noteworthy that tri- rather than di-phosphopyridine nucleotide was found to be the

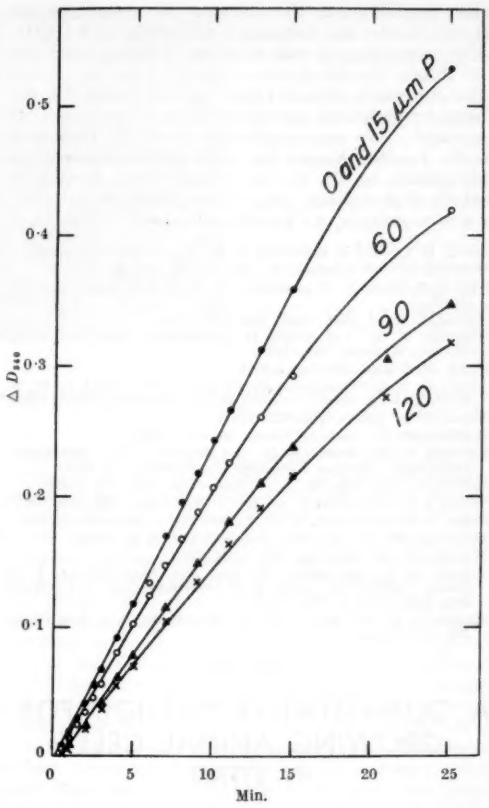

Fig. 2. Effect of phosphate concentration on the oxidation of glyceraldehyde-3-phosphate by enzyme in fraction *B*. Conditions same as in legend for Fig. 1 except that glyceraldehyde-3-phosphate was generated *in situ* by the action of crystalline aldolase (0·1 mgm. protein) on 10 micromoles of fructose-1,6-diphosphate

dominant pyridine nucleotide of green leaves[15]. The distinctive features of the glyceraldehyde phosphate dehydrogenase system in photosynthetic tissues are of interest in view of the identification of glyceric acid phosphate as the principal early product of photosynthesis[16].

The enzyme extracts were prepared from acetone powders of mature sugar-beet leaves grown in synthetic nutrient solutions in a greenhouse. Fraction *A*, the new TPN-specific enzyme, was isolated as the dialysed 50–60 per cent ammonium sulphate fraction of the leaf extract. This enzyme had no diphosphopyridine nucleotide activity. Fraction *B* was isolated from the filtrate of a heated leaf extract (4·5 min. at 58° C.), as the 50–70 per cent ammonium sulphate fraction. Although enzyme *B* had some diphosphopyridine nucleotide activity, the available evidence makes it highly unlikely that the triphosphopyridine nucleotide activity of this fraction is due to a transhydrogenase[17]. Enzyme *C*, which is specific for diphosphopyridine nucleotide, was readily isolated as the 80–90 per cent ammonium sulphate fraction; it had no triphosphopyridine nucleotide activity, and catalysed a reaction dependent on phosphate concentration[2,3], as would be expected from equation (1). The oxidation of glyceraldehyde-3-phosphate was measured in a Beckman model *DU* spectrophoto-

meter by following the increase in absorption at 340 mμ due to the formation of DPNH or TPNH[2].

This investigation was aided by a grant from the U.S. Public Health Service. One of us (D. I. A.) wishes to thank Misses Inger Agerberg and Gunilla Wessel for technical assistance in the early phases of the work[1]. We are indebted to Prof. E. Baer and Dr. D. L. MacDonald for gifts of glyceraldehyde-3-phosphate, to Dr. R. W. Cowgill for a sample of fructose diphosphate, and to Dr. Mary Belle Allen for a pure culture of *Chlorella variegata*. [Feb. 3.

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A QUANTITATIVE METHOD FOR GROWING ANIMAL CELLS *IN VITRO*

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THE study of the growth of metazoan cells as opposed to that of micro-organisms has been severely handicapped by the lack of quantitative methods suitable for direct measurements of cell multiplication and for chemical analysis.

In ordinary tissue-culture methods, the explant tends to degenerate to such an extent that the loss may for a time exceed the gain in newly formed cells. The very small net increase in living matter and the complexity inherent in such a system make direct measurements of growth impracticable. Methods tried in the past include measurements of the area of the colony, of the numbers of mitoses, of wet and dry weights, of metabolic activities, and of such tissue components as nitrogen and phosphorus fractions, particularly the deoxyribonucleic acid phosphorus. All these, however, are either inaccurate or they require the killing of the culture, or both. A discussion of these various techniques and a list of references can be found in a review by Parker[1] and in a recent monograph by Willmer[2]. An important advance, introduced by Earle and his collaborators[3,4], is the cultivation of cell suspensions obtained by mechanical disintegration of tissues cultured *in vitro* for long periods. The method, however, is not applicable to fresh tissues, and prolonged cultivation may produce cellular variations or even malignant transformation[4]. Moreover, quantitative recovery and the determination of cell number are obtained by making a suspension of dead and stained nuclei[5], which is a disadvantage for chemical work.

In an endeavour to overcome these difficulties, a technique of cell culture has been developed which is fairly simple, accurate and reproducible; it provides large quantities of living cells in suspension from a wide variety of tissues under physiological conditions, gives a good rate of growth, and yields a final product consisting of an even suspension of viable cells, suitable for counting, chemical analysis and further cultivation. Analytical results can thus be expressed per cell.

The method is based on the fact that viable cells can be freed from tissues by digestion with trypsin. Trypsin preparations have been used in the past for separating cells on a microscopical scale by Rous and Jones[6] and by Willmer[7] and others. The use of trypsin for the transplantation of cell cultures has now found wide application in the field of virus research[8]. Lately, Moscona[9] succeeded in disintegrating very young embryonic rudiments by digestion in a crude trypsin preparation in saline which has been freed from calcium and magnesium ions. These divalent cations are known to increase the stability of the intercellular matrix in both connective and epithelial tissues[10] and may have a protective effect against trypsin digestion[11].

By a modification of Moscona's method, cell suspensions were obtained on a larger scale from a variety of embryonic, adult and malignant tissues directly from the living organism, including heart, liver, skin, skeletal muscle, brain, intestine and spleen. A brief description of the technique has been communicated to the Physiological Society[12].

Quantitative work has so far only been done on suspensions obtained from embryonic chick heart, which is a standard tissue-culture material. The cells are centrifuged down, resuspended evenly in culture medium, counted with a hæmocytometer and inoculated in flasks or roller-tubes. Cells tend to become spherical while in suspension, but they soon spread out when allowed to settle on a glass surface or in a film of plasma. A nutrient fluid medium is added—consisting of 10 per cent concentrated embryo extract, 20 per cent horse serum and 70 per cent Tyrode with 0·5 per cent glucose (pooled and frozen-dried in aliquot portions to ensure a uniform composition)—and the whole surface of the container is gradually covered by a dense network of tissue cells (Fig. 1). At any stage of cultivation, the cells can be quantitatively re-suspended by trypsin digestion in calcium-

Table 1

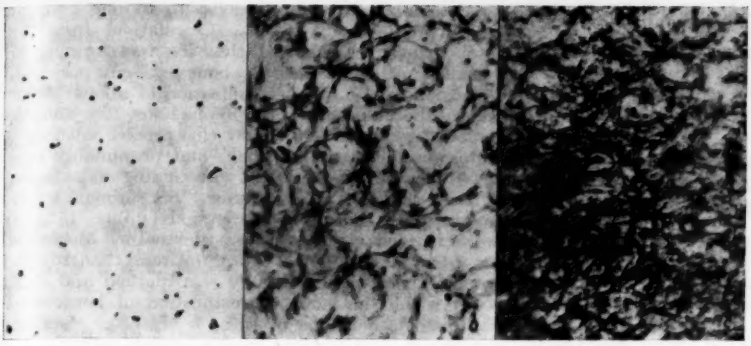
Average number of cells planted per tube	165,000
Average number of cells recovered after trypsin digestion for 20–60 min.*	169,000
Number of tubes	12
Standard error of the final counts	4,650

* The usual digestion time is 5–10 min.; these figures show that no loss of cells results from a longer incubation. Between planting and digestion the cells stood at room temperature without nutrient medium so that no growth could take place. (The small apparent increase is within the error of the method.)

Table 2

Experiment No.	Number of tubes	Average increase in cell number (n/n_o)	Standard error of the mean
1	5	9·8	0·53
2	4	6·8	0·56
3	8	10·06	0·74

The conditions differed from one experiment to the other. Within any one experiment, the conditions remained, so far as possible, identical for all tubes.



(*a*) 0 hr. (*b*) 4 hr. (*c*) 24 hr.

Fig. 1. Three stages of a culture of isolated cells from embryonic heart tissue (first subcultivation). × 60. Fixed and stained

and magnesium-free medium (Table 1) and their number determined either by nephelometry or preferably by hæmocytometer counts. Table 2 shows that within each series of tubes seeded with aliquots of the same cell suspension and cultured under identical conditions, the deviations are negligible as compared with the rate of increase.

The non-viable cells which die during the first day or two of cultivation can be eliminated by re-digestion with trypsin, and a suspension of practically 100 per cent viable cells is obtained for subcultivation. The resistance of living cells to tryptic digestion was known to Claude Bernard and has been demonstrated by Northrop[12], who showed that the selective digestion of dead cells is due to changes in permeability occurring with cell death. A further advantage to be derived from the use of trypsin is that both the plasma film, when present, and the intercellular matrix that may be formed during cultivation, are readily digested and can be washed away so as to avoid contamination of the cells with non-cellular components.

The growth curve (Fig. 2) shows many similarities with those of bacterial populations: there is an 'apparent' lag (approximately 48 hr., with fresh suspensions obtained *ex vivo*), a 'true' lag (about 3 hr., with subcultured strains); a logarithmic phase, and a stationary phase. The inocula used in these experiments were of the order of 1–5 thousand cells per cm.^{2} of culture vessel surface and per 0·1 ml. of medium.

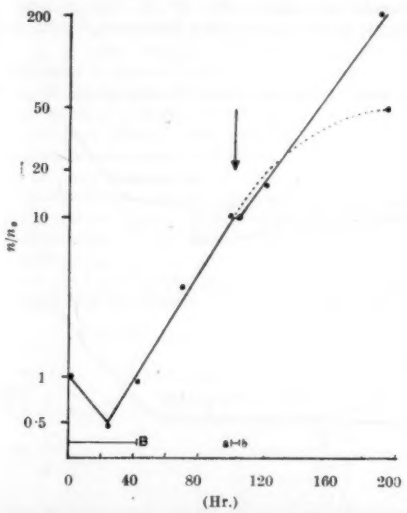


Fig. 2. Growth curve of a population of isolated tissue cells. The initial cell suspension was obtained *ex vivo* from a 12-day chick embryo heart. Each point is an average of several tubes. The arrow indicates subcultivation. The dotted line shows the growth of a non-subcultured aliquot. *A*—*B*, 'apparent' lag; *a*—*b*, 'true' lag

The logarithmic phase, as in bacteria, has the form $n = n_0 \exp kt$ (where n is present cell number and n_0 is initial cell number), but since the growth-rate of these cells appears to be about a hundred times slower than that of most bacteria, one may conveniently express t in hours instead of minutes and leave the order of magnitude of k unaltered. Under the conditions of these experiments, the cell population doubles approximately every 24 hr.—corresponding to a mitotic index of about 4 per cent—so that by subculturing before the growth-rate declines, a 200-fold increase in cell number may be obtained in eight days. If the cells are not transplanted, overcrowding results in a flattening of the growth curve even if the nutrient medium is renewed. If embryo extract is omitted, no increase in number takes place but the cells survive indefinitely in interphase.

These populations of isolated cells respond readily to changes in composition of the medium and are thus a sensitive material for the assay of growth promoters and inhibitors, metabolites, synthetic media, and possibly virus multiplication. For metabolic work the cells can be grown in Warburg manometer flasks; and for critical microscopy and ciné recordings, they can be grown in small coverslip chambers. Under these conditions it has been possible to observe single cardiac myoblasts beating spontaneously after several passages *in vitro*.

A fuller description of the method will be published elsewhere. I am indebted to Dr. H. B. Fell, Dr. E. N. Willmer and Dr. W. Jacobson for their comments and suggestions.

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LETTERS TO THE EDITORS

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Resuscitation of Hamsters after Supercooling or Partial Crystallization at Body Temperatures Below 0° C.

A VARIETY of cells and tissues of mammals survive for long periods at the temperature of 'dry ice', − 79° C., when frozen in media containing glycerol[1]. At the other extreme, Andjus's work on the whole animal shows that, by special methods of cooling and rewarming, rats can be revived from deep body temperatures of about + 0·5° C.[2]. We are now attempting to close the gap between these two lines of work (*a*) by increasing the size and complexity of the isolated tissue cooled to − 79° C., as, for example, by freezing a whole isolated organ[3], and (*b*) by reducing the whole animal to a body temperature below zero. This communication deals with experiments on the second of these developments.

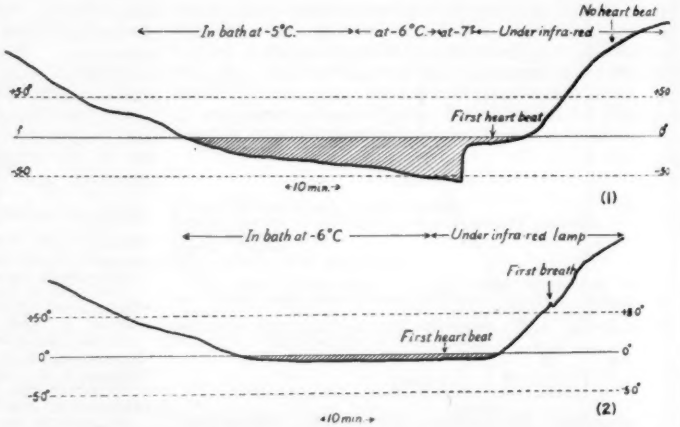
Hamsters, chosen because of their known adaptability to body temperatures between 2·5° and 38° C.[4], were cooled by the method recently described by Andjus and Smith[5] for rats. After transfer to icy water, the deep body temperature was recorded from a colonic thermocouple connected to a potentiometer or a microvoltmeter recording with an accuracy of ± 0·3 deg. C. In our experience the hamster ceases to respire at body temperatures between + 2·5° and + 6° C., and heart beats are no longer visible at + 1·8–3·5° C. Revival did not take place spontaneously from + 2°, but was readily effected by the method described for rats. After cessation of respiration, the animal was transferred to a 50 per cent propylene glycol bath maintained at − 4° to − 7° C., which reduced body temperature to zero in 7–10 min. Under these conditions, some animals became supercooled so that body temperature might reach − 5·5° C. or even below in a further 50–70 min. Four such animals removed from the cold bath while still supercooled at − 3° to − 5·5° C. were flaccid and were revived completely by the application of heat and artificial respiration. In eight others, supercooling to various points down to − 5·75° C. was abruptly terminated by a sudden rise of colonic temperature to a level slightly below − 0·5° C., although the animal was still immersed in the cold bath. Stiffening began simultaneously, confirming that crystallization of at least a part of the water of the body had taken place. In such animals, complete recovery has only twice been obtained, after relatively slight supercooling to − 1·4° and − 2·5° C., although in every case the heart has responded to rewarming.

The majority of animals cooled below zero started to freeze peripherally and the colonic temperature-curve flattened out at a mean level of − 0·6° C., showing no detectable drop for periods up to one hour in a bath at − 4° to − 7° C. Calculations from the rate of heat loss showed that ice was forming in such animals at the rate of about 0·25 gm. per min., corresponding to the crystallization of about 15 per cent of the total body-water in one hour. The animals stiffened progressively during this process until they were wood-like to the touch, and presumably consisted of a hard frozen shell surrounding an unfrozen or only slightly frozen interior. Six animals frozen under these conditions for periods up to 15 min. were revived completely by the method described for rats; seven animals frozen for more than 15 min. were revived imperfectly by this method and died, some within an hour of restoration of heart beat only, and others one to three hours after resuming respiration. Complete revival after freezing for 16–38 min. has been effected in nine animals by modified methods, including the use of diathermy for deep and rapid heating of the whole body and omission of the warm bath.

When the colonic temperature had become stabilized for some minutes in the animals undergoing crystallization, the extremities intimately exposed to the bath fluid at − 4° C. to − 7° C. were severely frozen—the ears, for example, attained the consistency of cardboard, and may well have undergone crystallization of 80 per cent of their water content. It is remarkable, however, that damage obviously due to this cause has been seen in only two of the twenty-one animals revived completely, some of which have been kept for many weeks afterwards in apparently normal health. It remains to be determined whether the use of propylene glycol in the cooling bath may have affected the reactions of the superficial tissues.

So far, no definite difference in behaviour below zero has been observed in hamsters pre-fed on propylene glycol, but work on this line is proceeding, as well as on methods of resuscitation, of cooling rapidly through the crystallization zone and on the physical reactions of whole mammals at very low temperatures.

Our thanks are due to Mr. W. C. Lister, head of the Instrument Division of the Institute, for his help



The colonic temperature of hamsters (of approximately 100 gm. body-weight) immersed in cold baths and rewarmed by radiant heat on the thorax.
(1) Below 0° C. for 52 min. Supercooling to − 5·75° C. followed by spontaneous rise to − 0·6° C. in bath at − 7·0° C. Resumption of heart-beat after rewarming for 3 min. with colon below 0° C.
(2) Below 0° C. for 47½ min. Progressive freezing in bath at − 6° C. with temperature curve flattening out at about − 0·7° C. Resumption of respiration after rewarming for 22 min.

with the supply of apparatus, and to Mr. E. A. Piper for technical assistance.

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Exchange of Bone Calcium and Phosphorus *in vivo*

The value of the radioactive isotopes of calcium and phosphorus in studies of bone growth has been called in question[1] owing to the difficulty of distinguishing between newly deposited bone and old bone which has become labelled by exchange. This view originated as a result of short-term experiments with rats, in which the activity of the calcium or phosphorus in portions of bone was compared with the activity of the serum at varying times after the administration of a single dose of calcium-45 or phosphorus-32 either by injection or by stomach tube. Tomlin, Henry and Kon[2] have criticized these experiments on the grounds that the specific activity of the serum is unreliable as a standard owing to the rapid variations which it undergoes after a single dose of an isotope, and because of the impossibility of discriminating between new and old bone by the method used. They have shown that, when calcium-45 is fed to rats continuously for several weeks, it is possible by means of an autoradiographic technique to distinguish effectively between new and old bone and that, in animals initially 30 days of age, the exchange of calcium is approximately 15 per cent after treatment for 30 days with the isotope. *In vitro* experiments with powdered bone using both radioactive calcium and phosphorus have given exchange percentages of a similar order[3].

In an experiment in which calcium-45 and phosphorus-32 were fed continuously to laying pullets eight months of age, we have studied the exchange of calcium and phosphorus in the tibia and femur by comparing the specific activities of these elements in cortical and medullary bone. Medullary bone, found in the marrow cavities of many bones of the avian skeleton before and during the laying period, undergoes a most intensive metabolism, periods of bone formation alternating with periods of bone destruction every few hours[4]. It is therefore a very suitable standard against which the activity of cortical bone labelled by exchange may be judged, and in the tibia and femur it can be completely separated from cortical bone by scraping. A direct comparison between 'new' and 'old' bone is thus possible.

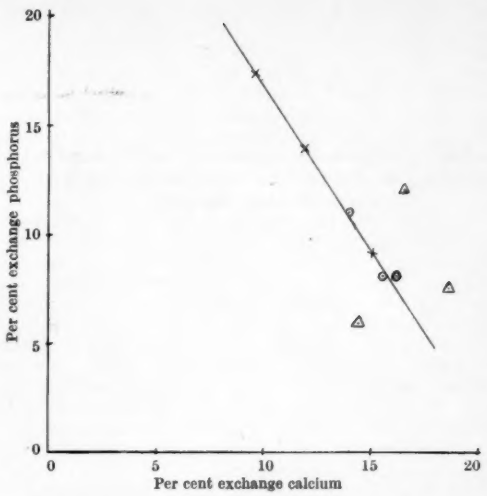

Fig. 1. Relationship between the percentage exchange of calcium and phosphorus shown by various bones.
△, Control birds; ○, two-egg birds; ×, six-egg birds

Four of the pullets were fed a meal extremely low in calcium, after laying three eggs on a normal calcium ration. Birds 1 and 2 laid six eggs on the deficient diet, and during this period it was calculated from balance and slaughter results that their skeletons had lost 38 per cent of the calcium present at the start of the low calcium regime. Birds 5 and 7 laid two eggs on the deficient diet and their skeletons lost respectively 15 and 17 per cent of the calcium initially present. Birds 3 and 8 were controls, and these were killed immediately after they had laid three eggs on the high-calcium ration[5].

The accompanying table shows the mean specific activities of the calcium and phosphorus from the tibia and femur of the six experimental pullets and the calculated percentage exchange of both elements. The specific activities of the serum phosphorus are also given; but it was not possible to obtain accurate figures for the activities of the serum calcium owing to the small amount present. The isotopes were fed

Bird No.	Bone	Phosphorus				Calcium			Days radioactive treatment
		Specific activities (counts/min./mgm. P)			Per cent exchange	Specific activities (counts/min./mgm. Ca)		Per cent exchange	
		Serum	Cortical	Medullary		Cortical	Medullary		
1	Femur	170	25·7	147	17·4	4·80	49·8	9·6	23
1	Tibia	170	21·6	154	14·0	5·40	45·2	11·9	23
2	Femur + tibia	182	14·6	159	9·2	6·30	41·8	15·1	23
3	Femur	305	15·2	258	5·9	3·45	23·9	14·4	21
3	Tibia	305	19·4	260	7·5	4·45	23·9	18·6	21
5	Femur	197	14·8	183	8·1	3·90	24·1	16·2	21
5	Tibia	197	21·6	196	11·0	3·60	25·8	14·0	21
7	Femur + tibia	206	16·2	199	8·1	4·30	27·6	15·6	20
8	Femur + tibia	237	21·8	180	12·1	3·50	21·1	16·6	14

for periods varying from fourteen to twenty-three days, and there is no indication of any increase in exchange within the period of time studied. The exchange percentages for both calcium and phosphorus are somewhat variable, but there is a marked reciprocal relationship between the figures for the two elements (Fig. 1), which may be related to the similar relationship known to exist between the diffusible calcium- and phosphorus-levels in the blood.

The differences between the rates of exchange of the calcium and phosphorus in different bones from the same bird are most reasonably explained on the assumption that local variations in the concentrations of serum calcium and phosphorus occur; but further work is necessary before any particular mechanism whereby this is achieved can be implicated.

The exchange percentages are similar in magnitude to those reported by Tomlin *et al.*[2] for young rats fed calcium-45 for thirty days, thereby confirming the view of these authors that the incorporation of radioactive tracers into bone minerals by exchange does not occur to such an extent as to preclude their use in studies of bone growth.

Autoradiographs prepared from the femur of a pullet of the same group which was fed calcium-45 for fourteen days showed that they were still growing, so that the exchange percentages obtained by the method described are probably slightly overestimated.

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Ammonia-formation Systems in Brain Tissue

An intimate relationship between nervous activity and ammonia formation had already been suggested by Tashiro[1], and recently Richter and Dawson[2] have pointed out the great significance of the rapid formation of ammonia in brain tissue, relating brain activity to functional metabolism.

In brain tissue, as is well known, the explosive formation of ammonia is observed in the excited state or after decapitation. We are interested in the functional significance of such an explosive formation of ammonia, and we describe here our experimental results on the sources of ammonia formation.

Weil-Malherbe[3] has discussed possible sources of brain ammonia. We have analysed the following three enzymatic reactions in brain tissue because they were believed[4] to be the most likely physiological sources of rapid formation of ammonia: (1) glutamic dehydrogenase, (2) glutaminase, and (3) adenylic deaminase.

The experimental animal was a guinea pig. The animal was guillotined, the head was immersed in liquid air instantaneously, the completely frozen brain was homogenized and was incubated without substrates in Krebs–Ringer solution at 37° C. The ammonia formed was determined using the micro-diffusion method[5], and at the same time glutamic acid, glutamine, and adenylic compounds were estimated. The Krebs–Ringer phosphate solution was of high potassium content (150 m*M*) and the *p*H was adjusted to 7·0. Glutamine was also determined by a micro-diffusion method, using the method of Richter and Dawson[2]. Glutamic acid was estimated manometrically by the modified Krebs decarboxylase method using the Japanese squash preparation[6], which did not decarboxylate glutamine, aspartic acid, pyruvic acid, and α-ketoglutaric acid. Adenylic compounds were determined in a Beckman model *DU* quartz spectrophotometer in a 5 per cent perchloric acid extract.

The main experimental results are summarized in Table 1. After 10 min. incubation, a considerable amount of ammonia was formed, and at the same time the glutamic acid content decreased markedly; but glutamine rather increased, and adenylic compounds were scarcely deaminated. These results show that the main source of ammonia during the first 10 min. was glutamic acid.

Table 1. Ammonia Formation in Guinea Pig Brain

Brain homogenate (without substrate)				
Incubation	0	10	30	min. at 37° C.
NH_3-nitrogen	0·37	2·53	3·21	mgm./100 gm.
Glutamine	22·5	25·9	32·2	mgm./100 gm.
Glutamic acid	197	152	136	mgm./100 gm. (as sodium salt)
Adenylic compounds	3·2	3·1	1·7	μM/1 gm.

Brain homogenate (in the presence of glutamate, 1/50 *M*) after 30 min. at 37° C.

	Liquid air		Ice-cold bath		
	Control	Glutamate	Control	Glutamate	
NH_3-nitrogen	3·14	3·71	5·62	3·65	mgm./100 gm.
Glutamine	32·7	41·3	62·5	110	mgm./100 gm.

Brain slice				
Incubation	0		40	min. at 37° C.
NH_3-nitrogen	1·45		2·29	mgm./100 gm.
Glutamine	39·0		41·5	mgm./100 gm.
Glutamic acid	112		—	mgm./100 gm. (as sodium salt)
Adenylic compounds	2·1		2·0	μM/1 gm.

Next, after 30 min. incubation, ammonia further increased slowly; glutamine also increased. Hence, glutaminase was functioning as an ammonia-binding mechanism rather than as an ammonia-forming system. On the other hand, glutamic acid further decreased, and adenylic compounds clearly changed over to inosinic compounds, accounting for about 1·9 mgm. per cent of ammonia (Fig. 1). Accordingly, the ammonia sources of this second stage were both glutamic acid and adenylic compounds.

Moreover, after 50–90 min. incubation, ammonia formation continued and glutamine decreased slowly, and it was shown that in this period glutamine deamination was more active than glutamine synthesis. When L-glutamic acid was added to brain homogenate prepared in an ice-cold bath, the formation of ammonia decreased, clearly showing that glutamine synthesis alone was increased by added glutamic acid due to the deficiency of diphosphopyridine nucleotide. But when L-glutamic acid was added to the homogenate of brain which was frozen in liquid air immediately after decapitation, the formation of ammonia rather increased. Of course, in both these cases, there was a significant increase in glutamine.

So far as the decrease of glutamic acid content in brain tissue is concerned, we must consider the

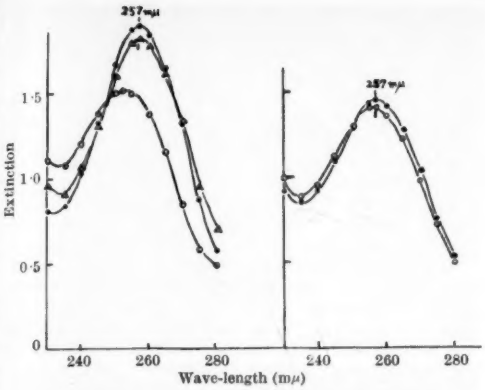

Fig. 1. Ultra-violet absorption curve of perchloric extract of brain tissue: left, homogenate; right, slice. ●—●—, 0 min. at 37° C.; △—△— (homogenate only), 10 min. at 37° C.; ○—○—, 50 min. at 37° C.

reactions of transaminase and glutamic decarboxylase besides the synthesis of glutamine; but we cannot explain such a great decrease of glutamic acid without considering glutamic dehydrogenase, which was also found to be present from our other experiments.

It is interesting that glutamic acid, which has an important role on the functional metabolism of brain, is concerned directly in ammonia formation systems.

We are also studying ammonia formation in brain slices, and the details will be published separately. One point may be mentioned here. When the brain slices were incubated in Krebs–Ringer solution in absence or in presence of substrates at 37° C. for 60–90 min., the adenylic compounds in slices were not deaminated. In slices, unlike in homogenate, the adenylic deaminase is quite inactive. It is quite probable that ammonia formation in brain slices during the first 30 min. incubation is mainly due to glutamic dehydrogenase, because during such a short period the autolysis or the deamination of glutamine can be neglected.

Recently, Weil-Malherbe[7] has reported the amination of inosinic acid. We can confirm the increase of ammonia formation, but cannot detect the amination of inosinic acid spectrophotometrically, when inosinetriphosphate was added to brain slices in which adenylic deaminase activity was inactive. Because the amount of glutamine decreased markedly, it was considered that the role of inosinetriphosphate was as an activator of glutaminase.

A detailed report of this work will be published in due course.

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Rehydration of Human Red-Cell Ghosts

The thickness of the surface ultra-structure of the dried red-cell ghost, as measured with the electron microscope or with the leptoscope, can be converted into the thickness of the undried surface ultra-structure only if the amount of hydration is known. If one allows for differences in method and for the loss of protein and lipid which may occur during the preparation of ghosts from red cells, there is agreement, to an order of magnitude, among most of the values which have been obtained for the thickness of the dried ultra-structure (200 A., Waugh and Schmitt[1]; 150–300 A., Wolpers[2]; 300–800 A., Bernhard[3]; 1000 A., Bessis and Bricka[4]; 140–1000 A., Latta[5]), but there are only two estimates of the amount of hydration. These are a hydration of 25 per cent at most (Waugh and Schmitt[1], on the basis of leptoscopic measurements), and a hydration so great that the protein-containing layer of the surface ultra-structure would be about 5000 A. thick and would contain only about 2 per cent protein (Mitchison[6], on the basis of birefringence measurements). Any additional evidence which bears on the degree of hydration of the ghost is interesting in view of the discrepancy among the existing estimates.

Ghosts of human red cells are prepared by hæmolysing the washed red cells of fresh heparinized human blood in 100 volumes of carbon dioxide-saturated 0·05 per cent sodium chloride and keeping the hæmolysate at 4° C. overnight. This gives a good yield of discoidal ghosts, with a volume about half that of the cells from which they were derived and containing about twice the concentration of hæmoglobin which is present in the surrounding fluid, that is, about 0·6 gm. per cent. These ghosts can be suspended in enough 0·05 per cent sodium chloride to give a suspension with a volume concentration of about 0·5, as measured either by conductivity or by the high-speed hæmatocrit; if the ghosts are freshly prepared from the washed cells of fresh blood, the values for the volume concentration given by the two methods agree closely. A volume of 0·5 ml. of the suspension is weighed in a small beaker; the beaker is then placed in a vacuum oven and its contents are dried in a gentle current of air at 25° C. The weight of the dried lipoprotein material is found; it varies with the completeness of the drying, but is usually 3–5 per cent of the weight of the wet material.

The dry material is rehydrated by adding 0·5 ml. of water to it. Gentle agitation, by drawing it up and down with a capillary pipette, disperses it throughout the added water. Examination of the ghosts with phase contrast usually shows them to be still flat and roughly circular bodies, although they are often fragmented; when the drying has been very thorough, however, they may be reduced to masses of formless material, in which case the experiment is rejected. Volume measurements made with the high-speed hæmatocrit show that the rehydrated ghosts occupy several times the volume which the dry material is calculated to occupy on the basis of its weight.

The mean value for the volume occupied by the rehydrated ghosts has been found to be 3·5 times the volume which the dry material would be expected to occupy on the basis of its weight and an assumed density of 1·1. The standard deviation in nine experiments was ± 0·26. If it is admitted that the final

state of rehydration is the same as the initial state of hydration, the surface ultra-structures of the ghosts used in these experiments contain about 33 per cent lipoprotein with associated hæmoglobin and about 67 per cent of water. It should be noticed that the thickness of the ultra-structure of these ghosts is probably greater than that of ghosts prepared by some other methods, for example, the method used by Waugh and Schmitt[1] in connexion with their leptoscopic measurements, or the method used to give the ghosts employed in Hillier and Hoffman's[7] electron microscope observations. It is not only possible but likely that the surface ultra-structure is made up of layers or regions, some more resistant to washing and probably less hydrated than others; the figure for the degree of hydration given by these experiments is therefore one for the average hydration of the whole surface ultra-structure of the ghosts as prepared by the method described.

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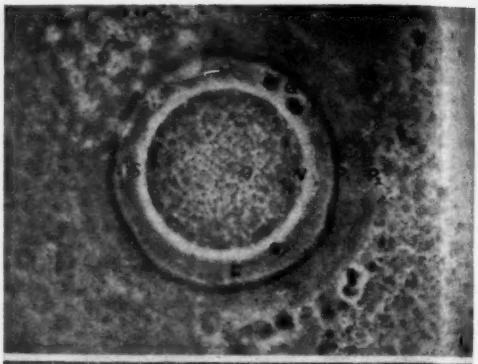
Observation of *in vitro* Fertilization in the Rabbit

In 1950[1] I showed that it is possible to obtain spermatic penetration of the pellucid membrane and the cytoplasm of oocytes of the female rabbit cultivated in fragments of Fallopian tubes to which spermatozoa taken from the vagina were added. This result was discussed in a symposium of the Ciba Foundation in 1952 on Mammalian Germ Cells[2,3].

A microcinematographic study of fertilization obtained *in vivo* followed by *in vitro* culture made possible the identification of a very characteristic aspect which can be used as a test for the first stage of fertilization of the oocyte of the female rabbit. It is the presence of mobile spermatozoa which are visible in the perivitelline space; the spermatozoa are included between the pellucid membrane and the vitelline membrane of the ovular cytoplasm that has shrunk after the penetration of the fertilizing spermatozoon, which in this position cannot be seen by direct examination. The presence of spermatozoa in the perivitelline space shows that the pellucid membrane has been penetrated by a fertilizing spermatozoon. Retraction of ovular cytoplasm is not always characteristic of fertilization[4].

A microcinematographic study has been made of *in vitro* fertilization. The technique is as follows: (*a*) After coitus with a sterile male (spermatic ducts tied), tubal oocytes are taken from the female rabbit (11 hr. after coitus). They are drawn into a pipette about 1 mm. in diameter, which has been filled beforehand with paraffin oil; the oocytes are placed in a watchglass in oil. (*b*) Another female rabbit is put with a normal male and the horn of the uterus is tapped 10 hr. after normal coitus; in this way it is easy to take 0·25 c.c. of uterine secretion containing a few thousand spermatozoa per cu. mm. (*c*) A few cubic millimetres of this secretion containing mobile spermatozoa is added to the oocytes. (*d*) The whole is cultivated under oil at 36·5°–37° C. in air or nitrogen.



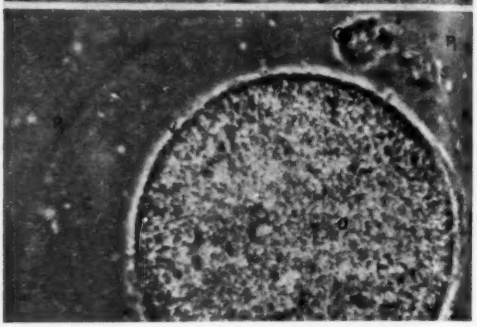


Fig. 1. Oocyte fertilized *in vivo* and cultivated *in vitro* in female rabbit serum. P_1, P_2, pellucid membrane; *G*, polar bodies; *V*, vitelline membrane; *E*, between *V* and P_1, perivitelline space; *S*, spermatozoa; *O*, retracted ovular cytoplasm

Fig. 2. Oocytes fertilized *in vitro* (tubal oocyte cultivated in the uterine secretion containing spermatozoa). P_1, pellucid membrane; *G*, polar body; *V*, vitelline membrane; *E*, perivitelline space; *S*, spermatozoon near a polar body; *O*, retracted ovular cytoplasm

It has been possible to record by microcinematography the arrival of a spermatozoon on the pellucid membrane, the retraction of the ovular cytoplasm and the differentiation of two lighter central zones corresponding to the pronuclei; it is also possible to observe the presence of spermatozoa in the perivitelline space. Under these conditions, segmentation of the ovum was not obtained. About 30 per cent of tubal oocytes are thus 'fertilizable' in the utero-tubal secretion containing spermatozoa[5].

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Photosynthesis of Amino-Acids from Paraformaldehyde and Potassium Nitrate

THE role of light in the synthesis of amino-acids and proteins in plants is still not very clear[1]. Previously it was believed that, in higher plants, synthesis of proteins is confined to the leaves[2] and might depend on light. It has been known that proteins are formed in leaves when there is an adequate supply of carbohydrates, and there is some evidence that the rate of protein synthesis in leaves is greater in the light than in the dark[3].

The parent substance from which higher plants derive their nitrogen is nitrate. This nitrate is reduced to nitrite in the roots and stem of plants. Schimper[4] has found that nitrites are always present in the living leaf in the dark and they disappear in the light.

I have now been able to synthesize amino-acids from paraformaldehyde and potassium nitrate with the help of light.

Three groups of three solutions each were prepared. Group 1 solutions contained 2 gm. of paraformaldehyde, and 1 c.c. of 6 *N* ferric chloride each. To the three solutions were added 1 gm., 0·5 gm. and 0·25 gm. of potassium nitrate respectively. The solutions were kept in 250 c.c. Sigcol beakers and 100 c.c. of distilled water was added in each. All three were exposed to bright sunlight for 80 hr. The temperature variation during the exposure was between 18° and 23·5° C.

A similar group of three solutions was kept in the dark. The third group, which was similar to the others but contained no ferric chloride, was kept in sunlight.

After an exposure of 80 hr. the solutions were tested for the presence of amino-acids by Giri's circular paper chromatography method[5,6] using butanol – acetic acid – water as solvent and ninhydrin as the developing reagent for producing colours with amino-acids.

Many of these amino-acids were qualitatively separated and their identification confirmed by circular paper chromatography as described by Giri, Krishnamurthy and others[7].

The solutions kept in the dark did not show the presence of amino-acid. Those containing no ferric chloride but kept in the light showed the formation of a few amino-acids, but the rings were very faint and no definite conclusion could be drawn. The solutions containing ferric chloride and kept in the light showed the formation of definite rings.

Among the solutions containing ferric chloride kept in the light, that containing 1 gm. of potassium nitrate gave rings identified as due to asparagine, serine, arginine and proline. However, two rings, one pale yellow of relative R_F 0·34 and another deep yellow of relative R_F 0·39, are also seen, which could not be identified. The solution which contained 0·5 gm. of potassium nitrate showed the presence of asparagine, arginine, serine, proline and ornithine. The solution which contained only 0·25 gm. of potassium nitrate showed the presence of valine, histidine, proline, lysine, serine, aspartic acid, glycine, asparagine and arginine. There also appeared a light yellow ring of relative R_F 0·57 and a dark yellow ring of relative R_F 0·43, neither of which could be identified.

All the three solutions containing ferric chloride and kept in the light became strongly acidic on exposure and their *p*H varied between 1 to 0·8. The solutions containing no ferric chloride and kept in the light had *p*H between 4·5 to 4·8 at the end. The solutions kept in the dark had *p*H about 6.

An attempt to separate these amino-acids from the mixture containing 0·25 gm. of potassium nitrate was made by circular paper chromatography, and crystalline serine, aspartic acid, glycine and asparagine were separated; only a few crystals of each were obtained. Attempts to separate histidine, arginine, lysine and proline have met with little success so far. Quantitative separation of these amino-acids will be undertaken shortly.

Preliminary analyses of only three of the separated amino-acids have been done so far.

Serine. On boiling with sulphuric acid it gave ammonia and pyruvic acid[8]:

$$OHCH_2—CH(NH_2)COOH \rightarrow CH_2=C(NH_2)—COOH \rightarrow CH_3—C(=NH)—COOH \rightarrow CH_3.CO.COOH + NH_3.$$

The amino-acid gave glyceric acid and a small quantity of acetaldehyde on treatment with nitrous acid. It was oxidized to glycolaldehyde[9] with periodic acid[10].

Aspartic acid. It formed a barium salt which was insoluble in alcohol. The acid did not pass over into pyrrolidone carboxylic acid in hot aqueous solution. This distinguishes it from glutamic acid[11]. The acid yields nitrogen on treating with nitrous acid.

The amino-acid gave a benzoyl derivative of melting point 162° C. and hydantoic acid, melting point 162° C.

Asparagine. On boiling the crystals of asparagine with hydrochloric acid, DL-aspartic acid was obtained. On boiling with dilute alkali, it yielded ammonia and DL-aspartic acid. It gave a picrate which decomposed at 175° C.; it produced α-naphthylhydantoic acid, melting point 199° C.

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Relation of Molybdenum Status and Nitrogen Supply to Respiration in Cauliflower Leaves

THE role of molybdenum in nitrate assimilation in higher plants[1], and the likely suggestion[2] that nitrate may provide a part of the oxygen requirement of plants, suggested an examination of the interrelationships of molybdenum and nitrogen supplies in respiration.

Leaf disks[3] 8 mm. diameter were sampled in groups of 15–30 from leaves of cauliflower plants grown in sand culture[4] with or without molybdenum and given nitrogen as nitrate, ammonium nitrate, ammonium sulphate, nitrite, ammonium nitrite or urea. Fresh and dry weights of samples were reproducible ± 2 per cent. Oxygen uptake and carbon dioxide evolution were measured in the Warburg apparatus in

Table 1. Values for Respiratory Quotient and $Q\bar{O}_2$ (μlit./gm./min.) obtained with Cauliflower Leaf Disks grown with Different Molybdenum and Nitrogen Supplies

Nitrogen source	Mo status	R.Q.	Q_{O_2} fresh	Q_{O_2} dry
Nitrate	+	0·93–1·09	0·30–0·51	2·17–2·83
	−	1·08–1·25	0·24–0·32	2·13–3·35
Ammonium nitrate	+	0·96	0·230	3·53
	−	1·11	0·265	3·37
Ammonium sulphate	+	0·94–1·10	0·39–0·395	2·24–2·68
	−	0·6 –1·07	0·40–0·44	2·68–2·90
Nitrite	+	0·95–1·00	0·40 –0·42	2·05–2·87
	−	0·96–1·10	0·375–0·40	2·57–2·10
Ammonium nitrite	+	0·95	0·365	4·15
	−	0·96	0·345	3·92
Urea	+	0·95–0·98	0·39–0·425	2·11–4·12
	−	0·94–0·99	0·28–0·355	2·51–2·66
Mean of nitrate group (13)	+	1·04	0·417	2·60
	−	1·14	0·260	2·83
	t =	4·40••• at 1%	5·93••• at 0·1%	1·10 n.s.
Mean of non-nitrate types (8)	+	0·97	0·398	2·89
	−	0·99	0·371	2·63
	t =	— n.s.	1·42 n.s.	0·028 n.s.

NO_3 − Mo vs. rest − Mo: $t = 5{\cdot}54$••• at 0·1 per cent.
NO_3 + Mo vs. rest + Mo: $t = 1{\cdot}84$ n.s.

a saturated atmosphere at 25°C. with 1·4 inches stroke, 120 cycles per minute in the presence of 1·0 ml. of 0·1 *M* phosphate buffer *p*H 5·5. Experiments were made in 1952 and 1953. Results showing respiratory quotients and Q_{O_2} on fresh- and dry-weight basis are given in Table 1, together with values for *t*, and its significance.

Disks deficient in molybdenum from plants grown with nitrate-containing nutrients consistently had higher respiratory quotients (carbon dioxide/oxygen) than either those from normal plants given nitrate, significant at 1 per cent level, or those from plants given non-nitrate treatments, significant at 0·1 per cent level, irrespective of their molybdenum status, which had no effect on respiratory quotient in these treatments, although the plants were deficient in molybdenum (− Mo)[5].

The Q_{O_2} values on fresh-weight basis were sharply decreased by molybdenum deficiency in the presence of nitrate and only slightly decreased with most other nitrogen sources. On a dry-weight basis the Q_{O_2} was possibly slightly increased with nitrate and decreased by non-nitrate treatments in the absence of molybdenum. The relative differences in Q_{O_2} for nitrate and non-nitrate nitrogen treatments are probably explained by the much lower dry-weight content in the molybdenum-deficient nitrate-grown plants than in the others.

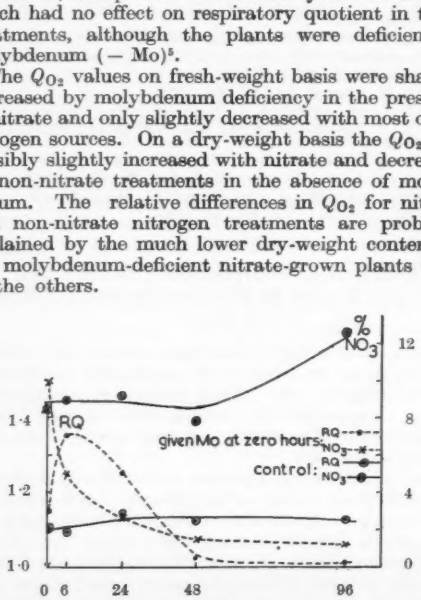

Fig. 1

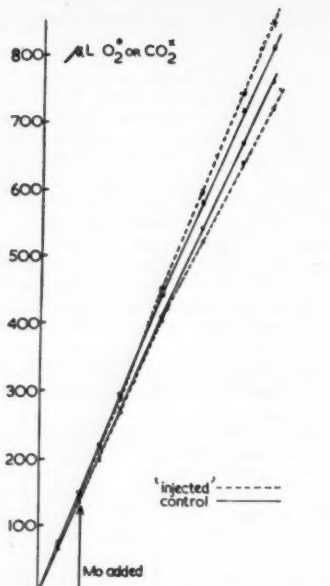

Fig. 2

Effects of injection of molybdenum were studied in two ways: (*a*) by giving 100 μgm. molybdenum to whole plants growing in a molybdenum-deficient culture and sampling at intervals; (*b*) by tipping 100 μgm. molybdenum ions from the side-arm of the Warburg flask during steady-state respiration of the leaf disks. Results with each method are shown in Figs. 1 and 2. (i) Injection of molybdenum into nitrate-fed plants by either method resulted in a further rise in respiratory quotient compared with non-injected control series lacking molybdenum. (ii) The inflated respiratory quotient then fell after some hours and decreased below the control (− Mo) value to the normal value (+ Mo) (Fig. 1) in the whole-plant experiment where prolonged sampling was possible. (iii) The leaf-disk experiment (Fig. 2) showed also that there was simultaneous increase in Q_{CO_2} and decrease in Q_{O_2} shortly after injection of the molybdenum-deficient disks. (iv) There was a rapid disappearance of accumulated nitrate after injection during the changes in respiratory quotient (Fig. 1).

Experiments on plants grown with a normal molybdenum supply or with nitrite or ammonium sulphate showed none of these changes; respiratory quotients remained normal about 0·96–0·98, and the plants contained negligible amounts of nitrate. Injection of nitrate from the side-arm during steady-state respiration of disks from plants of normal molybdenum status did not change the respiratory quotient.

The results obtained in the non-nitrate treatments suggest that respiratory balance is not greatly disturbed by molybdenum deficiency. The small decreases in Q_{O_2} might result from decreased sugar contents[5] and not necessarily from any direct effect

of molybdenum in respiration. There is no evidence at present to suggest an increase in anaerobic respiration in these circumstances. In the presence of nitrate, however, the respiratory mechanism appears to be modified. Q_{O_2} values (dry weight) in molybdenum-deficient leaves do not suggest a decreased oxygen uptake, and the increased respiratory quotient can therefore be due to three possibilities: (i) utilization of additional oxygen from nitrate; (ii) stimulation of anaerobic respiration; (iii) change of substrate.

The slightly greater respiratory quotient, 1·04, in nitrate plants than non-nitrate types, 0·99, given molybdenum and the rapid increase in respiratory quotient after injection of molybdenum into nitrate-fed molybdenum-deficient plants support the suggestion[2] that nitrate reduction provides an additional source of oxygen in respiration. The decrease in Q_{O_2} after injection of molybdenum into deficient material (Fig. 2) suggests here that oxygen in nitrate actually competes with atmospheric oxygen consumption during rapid reduction (Fig. 1) as well as causing increased evolution of carbon dioxide (Fig. 2). The origin of the initially high respiratory quotient in molybdenum-deficient plants given nitrate is less obvious. It may be due to a steady reduction of nitrate present in very high concentrations (5–13 per cent of dry weight) either mediated by a restricted nitrate reductase activity or through an alternative mechanism of low efficiency, or it may reflect the utilization of different substrates. It is hoped to elucidate some of these points in further studies.

This work was undertaken during the tenure of a special grant provided by the Agricultural Research Council under the Anglo-French Exchange Scheme by one of us (G. D.), for which grateful acknowledgment is made.

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Brownish-yellow Discoloration of Salt Cod and Halophile Calcium-needing Micro-organisms

In recent years the salt cod industry of Iceland has suffered heavy losses by the deterioration of the product caused by brownish-yellow discoloration. The deterioration sets in 10–20 days after salting, the flesh of the fish first becoming creamed and yellow and turning brownish-yellow to brown in three to five weeks. Such a deterioration has been observed in other countries, such as Canada and Great Britain.

Dyer[1] considered the staining to be caused by small amounts of iron in the fishery salts, and in the report of the Food Investigation Board for 1951 it is suggested that the browning may be of the Maillard type[2]. I have studied the phenomenon for the past four months and have come to the conclusion that the deterioration is caused by halophile calcium-needing micro-organisms. This conclusion was drawn from the following results.

In commercial samples of salt cod, the calcium content of the skin and bone-free deteriorated fish was found to be 0·28 per cent, that of the unspoiled fish 0·16 per cent (eight samples). The content of calcium in excess of sulphate was 0·20 per cent in the spoiled fish and 0·08 per cent in the unspoiled.

The content of calcium of the salt in the experimental stacks was reduced and the content of sulphate also, only much more. Thus the ratio calcium to sulphate for one sample of contaminated salt increased from 0·46 to 1·38 in forty-three days in the stack. For another stack with an excess of salt, the same ratio increased from 0·37 to 0·46 in seventeen days and to 0·54 in thirty-six days.

Sterilizing the salt by heating for 4½ hr. at 150–180° C. stopped the discoloration caused by the salts, as shown by salting experiments. Three samples were tested. Discoloration was increased by adding calcium chloride to the contaminated salts. No increase was noted by adding magnesium sulphate.

In one of the samples of fishery salts, there was 0·04 per cent calcium chloride, 0·02 in the second and none in the third.

One of the samples with a calcium content of 0·05 per cent caused discoloration when calcium chloride was added, but not otherwise.

It is concluded that the micro-organisms reduce the sulphate in calcium sulphate to obtain the calcium in a soluble form.

A detailed report of this work will be published elsewhere.

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Paper Chromatographic Examination of the Alkaloid Extract in Toxicology

Recent advances in chemotherapy present the police toxicologist with the problem of extracting and identifying from viscera an increasing number of basic organic compounds. In the past, methods of identifying less than milligram quantities of basic poisons extracted from the body have depended on colour reactions and micro-crystallography. Little is known of the fate of these new drugs in the body, and their reactions with the alkaloidal reagents are often unpublished. Paper chromatography is obviously the method of choice for the preliminary sorting on a microgram scale of these poisons from one another and from their metabolites.

We wish to report a solvent system which we have found to be most useful in separating compounds that may be found in this basic extract. The method of revealing the spots has been that of Munier and Machebœuf[1]. It has been found that the use of this modified Dragendorff reagent provides an additional criterion to the R_F value because it produces with different compounds a variety of shades of orange and red. 20 μgm. of a substance is easily detected.

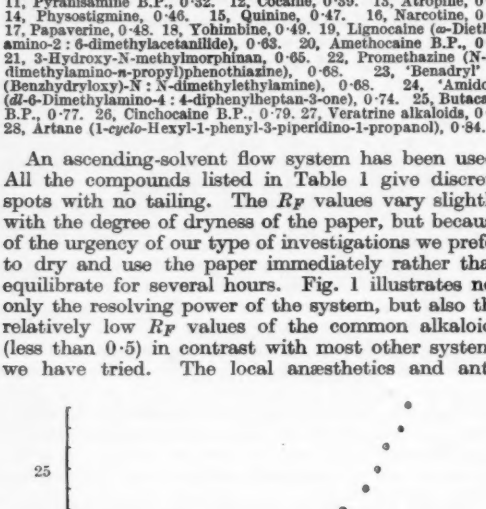
Where the extinction coefficient values are high enough, the position of the spots having been found by a comparative chromatogram, elution and the determination of the ultra-violet absorption spectrum provide further analytical data.

The solvent is *n*-butanol (50 ml.) : water (50 ml.) : citric acid (1 gm.). The upper layer is used. Before use the paper (Whatman No. 1) is dipped in a 5 per cent sodium dihydrogen citrate solution, any excess liquid removed by blotting, and then is dried at 60° for 25 min. This technique has been of great value in buffering the paper at the right *p*H for a good general separation. We have not experienced double zoning with this system, but did with a corresponding oxalic acid system (cf. ref. 2). We have found that the great value of this system is that of indicating, on a very small quantity of material, those poisons that may be present and those that can be eliminated from further consideration.

Table 1

1, Pethidine, 0·00. 2, Nicotine, 0·07. 3, Pilocarpine, 0·11. 4, Morphine, 0·12. 5, Brucine, 0·14. 6, Codeine, 0·16. 7, Hyoscine, 0·21. 8, Strychnine, 0·25. 9, Procaine, 0·27. 10, Diacetylmorphine, 0·31. 11, Pyranisamine B.P., 0·32. 12, Cocaine, 0·39. 13, Atropine, 0·42. 14, Physostigmine, 0·46. 15, Quinine, 0·47. 16, Narcotine, 0·47. 17, Papaverine, 0·48. 18, Yohimbine, 0·49. 19, Lignocaine (ω-Diethylamino-2 : 6-dimethylacetanilide), 0·63. 20, Amethocaine B.P., 0·65. 21, 3-Hydroxy-*N*-methylmorphinan, 0·65. 22, Promethazine (*N*-(2′-dimethylamino-*n*-propyl)phenothiazine), 0·68. 23, 'Benadryl' (2-(Benzhydryloxy)-*N* : *N*-dimethylethylamine), 0·68. 24, 'Amidone' (*dl*-6-Dimethylamino-4 : 4-diphenylheptan-3-one), 0·74. 25, Butacaine B.P., 0·77. 26, Cinchocaine B.P., 0·79. 27, Veratrine alkaloids, 0·82. 28, Artane (1-*cyclo*-Hexyl-1-phenyl-3-piperidino-1-propanol), 0·84.

An ascending-solvent flow system has been used. All the compounds listed in Table 1 give discrete spots with no tailing. The R_F values vary slightly with the degree of dryness of the paper, but because of the urgency of our type of investigations we prefer to dry and use the paper immediately rather than equilibrate for several hours. Fig. 1 illustrates not only the resolving power of the system, but also the relatively low R_F values of the common alkaloids (less than 0·5) in contrast with most other systems we have tried. The local anæsthetics and antihistamines as well as the various other common drugs have come within our experience.



While there is a growing literature on the separation of alkaloids (cf. ref. 3), we have found this to be largely concerned with alkaloids of the same group, or with alkaloids that are found together in medicinal preparations. We feel that this system, and this method of presentation, will be of use to the toxicologist who has the problem of separating and identifying any of the above compounds.

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Inhibition of the Crown-rot Disease Fungus, *Sclerotium delphinii* Welch

In 1952, I reported[1] the inhibition *in vitro* of the crown-rot fungus, *Sclerotium delphinii* Welch, by two species of *Penicillium*, *P. brevi-compactum* and *P. charlesii*. *In vivo* experiments were set up to demonstrate the practical utilization of these penicillia as agents in combating the crown-rot fungus disease. For this purpose the penicillia were grown in large quantities in Czapek–Dox medium for seventeen to eighteen days on a rotary shaker at room temperature. The culture fluid was then filtered and the filtrate was poured into standard greenhouse flats, containing soil which had been artificially infested three days before with sclerotia of *S. delphinii*. Controls were also set up, using Czapek-Dox medium, in flats of similarly infested soil. A few days after filtrates of different concentrations were added to the flats, nine plants of *Mazus reptans* and *Ajuga reptans* (two rock-garden plants extremely susceptible to *S. delphinii*) were planted in each of the different flats.

Although these experiments were started in late autumn, no symptoms of the crown-rot disease could be observed in any of the flats until early spring, as sclerotia lie dormant in the winter.

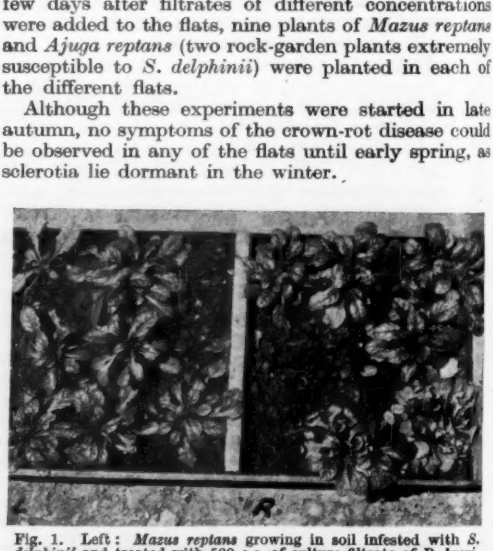

Fig. 1. Left : *Mazus reptans* growing in soil infested with *S. delphinii* and treated with 500 c.c. of culture filtrate of *P. brevi-compactum*. Two of the nine plants in this flat have died. Right : As a control, the same number of plants were set in similarly infested soil treated with 500 c.c. of Czapek–Dox medium solution only. Five of the nine plants are dead or are dying

The plants in the flats were examined periodically during the early part of the spring of 1952. On May 3, 1952, the following observations were made. In two of the treated flats there was definite evidence of the inhibition of the crown-rot fungus. In lot *A*, flat 25210, treated with 250 c.c. of the culture filtrate of *P. charlesii*, six out of nine plants were still healthy; whereas in the control flat of lot *A* only three of the nine plants were still unattacked. More striking results were obtained in lot *C*. In the flat, 25208, treated with 500 c.c. of the culture filtrate of *P. brevi-compactum*, only two out of the nine plants were dead, whereas in the control three plants were dead and two were dying (Fig. 1, *L* and *R*).

It is therefore evident that, at the right concentration, the metabolic products of *P. charlesii* and *P. brevi-compactum*, produced in Czapek–Dox medium are able to inhibit the development of the crown-rot fungus, *S. delphinii*.

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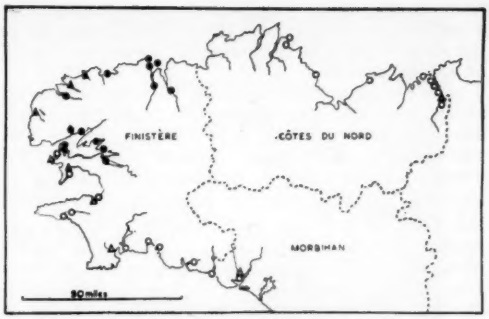
Elminius modestus in France

Elminius modestus Darwin was first recorded from Holland in 1946 [1] and has since spread over most of the coastline of the Low Countries[2]. Little information is available, however, on the presence of this immigrant barnacle in France, and the following observations may therefore be of interest.

In September 1950 *E. modestus* was present in large numbers on intertidal rocks and molluscs at Wimereux, Pas de Calais. Unfortunately, no further records could be obtained at that time; but in September 1953 further observations were made at Le Havre and at various points along the coast of northern Brittany. At this time *E. modestus* was abundant on rocks and jetties at Le Havre. With the exception of a single specimen at Port St. Hubert, it could not be found in the Rance estuary, an apparently ideal environment for the species, nor at any of the localities visited in the Côtes du Nord. In northern Finistère, however, the species was abundant in the Roscoff area and throughout the Rade de Brest, and was present at all intervening localities examined. South of the Rade de Brest only occasional individual specimens could be found, usually after prolonged searching, but these were recorded for as far south as Lorient. The observations made in Brittany are summarized in the accompanying map.

The observations presented here indicate that the spread of *E. modestus* from Belgium had passed the French frontier before the summer of 1950. The colonization at Le Havre may have resulted from a continuation of this westward extension of range, but the observations made in Brittany indicate that a separate centre of colonization has been established in northern Finistère. How and when this establishment was accomplished are unknown, but Dr. P. Drach informs me that *E. modestus* was settling in large numbers at Roscoff in the summer of 1952. The immigrant barnacle is now a prominent member of the littoral fauna of northern Finistère and has penetrated the muddy estuaries (for example, at Morlaix) beyond the limit of any other species of barnacle. The large size of some of the specimens found (up to 17 mm. carinorostral diameter in the Aber-Benoit and up to 14 mm. at other localities) is probably ascribable to highly favourable environmental conditions rather than to the age of the barnacles[3]. The presence of isolated individuals at considerable distances from the main area of settlement may be attributed to transportation on coastwise shipping, but it is unlikely that such specimens can reproduce sufficiently to build up new centres of immigration[4].



Distribution of *Elminius modestus* Darwin in northern Brittany in September 1953.
●, Abundant; ▲, present in considerable numbers but not abundant; △, present as isolated individuals only; ○, absent

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Determination of Absolute Configuration by Laue Photographs

When a non-centrosymmetric crystal is studied by using X-rays of the wave-length λ a little shorter than the *K*- or *L*-absorption edge (λ_K^Z or λ_L^Z) of some atom *Z* in the crystal, the *hkl* and $\bar{h}\bar{k}\bar{l}$ reflexions should, in general, have different intensities. This effect was first observed by Coster, Knol and Prins[1,2], using zinc sulphide and gold $L\alpha_1$ radiation. The same method was used by Peerdeman, van Bommel and Bijvoet[3], for sodium–rubidium tartrate and zirconium $K\alpha$ radiation, in their beautiful confirmation of the correctness of the Fischer convention for optically active molecules. Bijvoet has also pointed out possible applications of the method, for example, in phase determination for non-centrosymmetric compounds[4]. The practicability of such applications is limited, however, by the difficulties of the technique.

It seems to have been assumed in practice that the X-radiation used must be that of a characteristic spectrum; but it is by no means always easy to make an X-ray target of what may be the most suitable element and then to obtain from it characteristic radiation of sufficient intensity for crystal investigation. Neither the gold nor the zirconium targets

used in the above experiments were commercially available, and if the crystal were to contain iodine, the most suitable radiations would be lanthanum $K\alpha$, or xenon $K\beta$.

It is not necessary, however, to use characteristic radiation at all. Any X-ray tube gives a continuous spectrum containing all wave-lengths from a short wave-length limit which depends on the applied voltage. In a suitable crystal orientation, the *hkl* and $\bar{h}\bar{k}\bar{l}$ reflexions (or any reflexion equivalent to $\bar{h}\bar{k}\bar{l}$, such as $hk\bar{l}$, say, in $P\bar{4}3m$, may be used) will appear on a Laue photograph as a symmetrical pair of spots. The wave-length λ producing any given Laue reflexion *hkl* depends on the angle $\varphi(\lambda)$ between the planes (*hkl*) and the incident X-ray beam. If $\varphi(\lambda) = \varphi\left(\lambda\frac{Z}{K}\right) + 1°$ (say) for both (*hkl*) and ($hk\bar{l}$), a pair of reflexions of equal intensity should result, since for $\lambda > \lambda\frac{Z}{K}$ the imaginary part $\Delta f''$ of the anomalous dispersion correction is zero[5]. If, on the other hand, $\varphi(\lambda) = \varphi\left(\lambda\frac{Z}{K}\right) - 1°$ (say), the pair of reflexions will, in general, have unequal intensities. A doubly-exposed Laue photograph taken in both settings serves to confirm that the inequality in the short wave-length position is not due to crystal distortion or mis-setting. Care must, of course, be taken to avoid settings near the characteristic Bragg position for *hkl*, where in any event the earlier methods are applicable. Reflexions which include strong harmonics should also be avoided to gain full advantage of the effect.

Larger values of $(\sin\theta)/\lambda$ in general provide the most favourable conditions for observation of *hkl*, $hk\bar{l}$ intensity differences, but the effect can be observed at moderate angles. In the case of zinc sulphide the ratio $I(hkl) : I(hk\bar{l}) \approx 2 : 1$ for reflexions such as {551} and {731}.

We have observed this effect on Laue photographs of a 0·2-mm. zinc sulphide crystal, using ½-hr. exposures on a cylindrical film of diameter 6 cm., with a copper-target sealed-off commercial tube run at 35 kV.

The range of wave-lengths available from any normal target (tungsten, molybdenum, copper, iron, etc.) run at voltages of up to 50 kV. should enable the dispersion effect to be utilized for even the heaviest atoms. The exact limit of the usefulness of the method at the light atom end depends on a number of factors and has not yet been explored.

The continuity of the spectrum means that $\lambda - \lambda\frac{Z}{K}\left(\text{or } \lambda - \lambda\frac{Z}{L}\right)$ may be given any desired value and hence offers in principle a method of studying the detailed form of the dispersion curve, not limited to characteristic wave-length values of λ.

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Carbon-14 β-Track Autoradiography of High Resolution

Recent reviews and published methods of autoradiography give ready access to the various procedures which are now in general use[1–5].

All these methods recognize three major limitations of present procedures, namely, inadequate resolution, dissolution of the isotope, and error introduced by background fogging. The method described here overcomes these limitations, extending the range and accuracy of autoradiography to the limits of the light microscope, and allows the study of isotopic photosynthetic products soluble in water and organic solvents. Using Ilford *G5* nuclear track emulsion, low carbon-14 concentrations of the order of 5×10^{-10} gm./gm. of tissue can be detected. By β-track counting, quantitative estimates of activity contained in 5-μ and 7-μ sections of Biloxi soybean leaf have been determined, and by checking results against a methacrylate carbon-14 reference (Radioactive Materials, Radiochemistry Centre, Ministry of Supply) it is conceivable that determinations could be made absolute.

The dissolution of photosynthetic products containing carbon-14 has been prevented in tissue fixation by freezing-drying, and in the histological procedure by spreading the paraffin ribbon on anhydrous glycerine. Background fogging can be distinguished from tracks caused by the passage of β-particles through the highly sensitive emulsion. At the same time the accumulation of tracks from cosmic radiations has been kept to a minimum by pouring plates in the laboratory and making the photographic exposure within a 4-in. lead shield[6]. In this way background-track counts have been as low as 0·01, and not greater than 0·03 tracks per 60 μ^2 of the photographic plate. By placing glycerine-spread paraffin sections on the surface of *G5* plates, firm and intimate section-emulsion contact has been achieved. The majority of the sections remain undamaged throughout photographic processing, and this arrangement allows detailed association of tissue structure with β-track origin at the emulsion surface. If the unstained section adhering to the emulsion surface is immersed in a drop of ethyl alcohol under a No. 1 coverslip, both section and autoradiograph may be seen with a high-power oil-immersion objective. Two photomicrographs (Figs. 1 and 2), in which the tissue is slightly out of focus, are presented to illustrate the technique. Since, in the majority of cases, tracks enter the emulsion fairly steeply, only the first few grains are in focus in the photomicrograph. However, by focusing first on the tissue section, then to the emulsion surface and to lower depths of the emulsion, an overall picture of the cell and associated electron tracks is readily obtained. Single fog-grains which are readily distinguishable from tracks under working conditions may be confused with the origin of β-particle tracks when viewed at a single focusing level.

Figs. 1 and 2 are phase-contrast photomicrographs, magnification × 1,500, of the leaf cells and part of their underlying autoradiographs. It is clear that very close correlation between the tissue and emergent β-particle tracks is possible with this technique. Fig. 1 shows that tracks emerge from the tissue surrounding the vascular bundle in uniform concentration. The emulsion underlying the xylem vessels contains no β-particle tracks, demonstrating the absence of the products of photosynthesis from

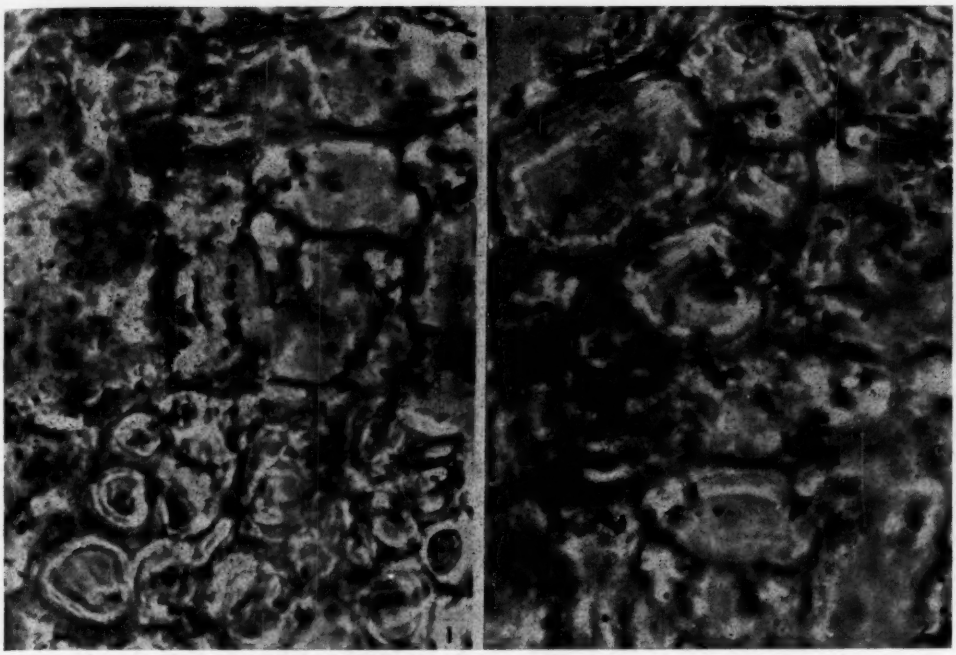

Fig. 1. An autoradiograph of a transverse section of Biloxi soybean leaf after assimilation of carbon-14 dioxide. The vascular bundle can be seen in the lower part of the photograph surrounded by cells of spongy mesophyll. × 1,500 (phase contrast).
Fig. 2. An autoradiograph of several spongy mesophyll cells. Seven particle tracks are associated with the cell marked in the centre of the photograph. × 1,500 (phase contrast)

the xylem. A spongy mesophyll cell in the centre of Fig. 2 gives rise to five tracks originating in the centre of the cell and two tracks (of low energy and at a wide angle) from the cell wall. Full details of the method and further demonstration of its application will be published elsewhere.

We wish to thank Prof. J. S. Turner for his encouragement and support throughout the period of the investigation, and Mr. A. E. Matthaei for the photomicrographs.

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High-order Focusing by a Uniform Magnetic Field with Straight-line Boundaries

An arrangement frequently used for magnetic focusing in mass spectrographs is the symmetrical one employing normal entry into, and exit from, a uniform magnetic field of sector shape. This gives only first-order focusing, as the straight-line boundaries are the tangents to the ideal symmetrical curve for perfect focusing as given by Hintenberger[1] and by Kerwin[2]. To obtain second-order focusing, Kerwin[3] has used as boundaries the tangents at the points of inflexion on this curve, the entry and exit of the particles being oblique.

Let us suppose that we wish to produce at a given point perfect focusing of all particles emitted with the same momentum from a given point source. This can be achieved by a uniform magnetic field of arbitrary boundary where the particles enter, provided the exit boundary is chosen to correspond. A special drawing instrument has been made which traces out the exit boundary automatically when a pointer on it is moved over the arbitrarily chosen entrance boundary. The curves obtained in this way have been studied with the view of selecting those of simple shape which will give accurate focusing of particles emitted over a wide angle and which will also give good focusing of particles of slightly different momenta. By an easy procedure, it is possible to choose the position of a straight-line entrance boundary so that the corresponding exit boundary cannot be distinguished by eye from a straight line over a distance comparable with the radius of curvature r of the particle path in the magnetic field. An example of this is shown in Fig. 1. O is the source of charged particles, I is the image where the particles are focused, and AB is the straight-line entrance boundary to the field. The corresponding exit boundary as traced out by the drawing instrument is ACD. It is so nearly straight from A to C that O and I might almost be described as aplanatic points for the field bounded by straight lines AB and AC. The extreme path for good focusing is $OECI$, and all particles emitted within the angle AOE are focused at I to a high order of accuracy. The values

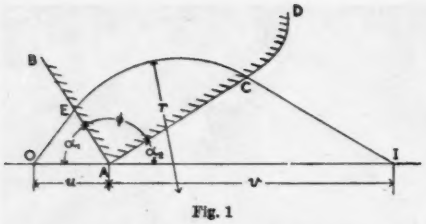


Fig. 1

of the constants for Fig. 1 are $\varphi = 91°$, $\alpha_1 = 57°$, $OA = u = 0{\cdot}57\,r$, $AI = v = 2{\cdot}15\,r$, $\angle AOE = 53°$.

For any given value of φ there is an optimum set of values of α_1, u/r and v/r which would determine the design of instrument with maximum aperture. Graphs of these quantities as functions of φ have been obtained.

If the exit boundary remains straight up to A (which can be ascertained by a simple test when selecting the entrance boundary), it is easy to show that u and v satisfy the relation $1/u + 1/v = (\cot\alpha_1 + \cot\alpha_2)/r$. This formula is the counterpart of the simple lens formula in optics and has been found to hold fairly closely in most of the optimum arrangements of practical interest. For any given values of u/r and v/r, a further condition is necessary in order to determine α_1 and α_2. This corresponds very closely with the condition for minimizing spherical aberration in geometrical optics by the procedure of 'bending the lens' while keeping its thickness at the centre constant. In the case of the magnetic lens the corresponding procedure is to keep constant the intercept cut off by AB and AC on a fixed parallel to OI, while turning AB and AC about A to make the aberration a minimum.

The arrangement shown in Fig. 1 also yields very good focusing of particles emitted from O with slightly different momenta. In Fig. 2, the dotted line gives the line of best focus for particles of various momenta, the radii of curvature (in cm.) of their paths being shown by numbers adjacent to the various images. The special drawing instrument was used to trace the ideal exit boundaries (labelled 7, 8, 9) corresponding to the images labelled 7, 8, and 9 on the line of best focus. The coincidence between these three curves over the greater part of the straight-line portion AC is very striking. The curves separate slightly between G and A. The figure shows that all particles for which r lies between 7 and 9 cm. and which are emitted within the angle FOE (= 34°) would be focused very accurately on the dotted line between points 7 and 9. A design of this type might be of importance in spectrographs combining good resolution with the large aperture necessary for weak sources.

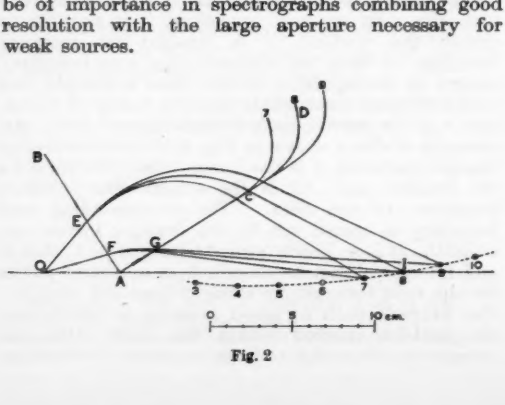


Fig. 2

No allowance has been made for the effect of fringeing magnetic field. This might be expected to modify only slightly the constants for the optimum design.

It is hoped to publish shortly full information on the solution of the problem as obtained from this drawing-board method of investigation.

E. T. S. Walton

Trinity College,
Dublin.
April 20.

[1] Hintenberger, *Z. Naturforsch.*, **3a**, 125 (1948).
[2] Kerwin, *Rev. Sci. Instr.*, **20**, 36 (1949).
[3] Kerwin, *Rev. Sci. Instr.*, **21**, 96 (1950).

Metal - Oxygen Bonds, and Co-ordination Complexes with Tetragonal Pyramidal Configurations

Our studies of certain compounds which the hæmoproteins form with peroxides and other strong oxidizing agents suggest that in these the iron is quadrivalent[1]. In the case of the most fully investigated compound, obtained by oxidizing ferrimyoglobin, the evidence indicates that an oxygen atom is bonded to the iron[2]. Such a compound would be a co-ordination complex of the hypothetical ferryl ion FeO^{2+}, and, since the iron – ligand bonds are covalent as judged from magnetic susceptibility studies[3], it could be envisaged as a familiar d^2sp^3 covalent octahedral complex with four Fe—N bonds in the plane of the porphyrin ring and two bonds at right angles, one between the Fe and the protein and the other between the Fe and the oxygen. Other complexes where similarly bonded oxygen atoms are well authenticated, and particularly complexes more closely related in gross chemical structure than obvious examples like the ferrate and manganate ions, are the uranium and osmium compounds, $UO_2(N\text{–base})_2\,X_2$, $OsO\,(NH_3)_4\,X_2$, and the complexes of quadrivalent vanadium.

The need to account for the V—O bond in these vanadyl complexes resulted in their being formulated in some cases as octahedral complexes with the oxygen atom functioning as a bidentate group: for example, the vanadyl lakes with azo-dyes for which Drew and Dunton state, "since the O-atom [is] doubly bound to the metal [it] can only occupy *cis* positions of the octahedron"[4]. Modern valency theory would require the oxygen to be a monodentate group held by one σ-bond. Double-bond character could then arise through interaction of p and/or d electrons, as perhaps is the case in the complex of ferryl ion cited above.

The vanadyl porphyrin and phthalocyanine provide better examples where bidentate bonding of oxygen, as envisaged by Drew and Dunton, is quite impossible. But the kind of configuration which these particular complexes possess raises a very interesting stereochemical question. If monomolecular and with no solvent molecule to complete sixfold co-ordination, they would be constrained to have the tetragonal pyramidal configuration; and even if they were polymerized with a sequence of —O—V—O—V— bonds, one terminal group would still have to be of this type. Such a configuration for a pentacovalent compound is extremely rare, the trigonal bipyramidal type being the more common. IF_5 provides an example, but the only metal co-ordination com-

pounds for which there is substantial evidence are the trivalent nickel and cobalt trialkyl phosphine derivatives, $Ni(PEt_3)_2Br_3$ and $Co(PEt_3)_2Cl_3$ [5]. The magnitude of their dipole moments enables a definite choice to be made. Later work has suggested that some oxidation products of nickel dimethylglyoxime, which also contain trivalent nickel, come into this category as well. The vanadyl porphyrin and phthalocyanine, known for a rather longer time, may also have to be included, along with some of the cobaltous complexes which readily take up oxygen gas in the molecular proportion of 1 : 1 to give octahedral complexes, notably the 3-Me and 3-Cl derivatives of cobalt di(salicylal-3,3′-diimino-di-*n*-propylamine)[6].

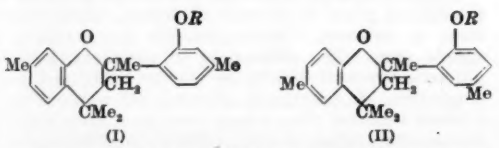
PHILIP GEORGE
D. H. IRVINE

Department of Colloid Science,
University, Cambridge.
March 25.

[1] George, P., and Irvine, D. H., *Brit. J. Rad.*, **27**, 131 (1954).
[2] George, P., and Irvine, D. H., "Symposium on Co-ordination Chemistry" (Copenhagen, 1954) (in the press).
[3] Theorell, H., and Ehrenberg, A., *Arch. Biochem. and Biophys.*, **41**, 442 (1952).
[4] Drew, H. D. K., and Dunton, F. G., *J. Chem. Soc.*, 1064 (1940).
[5] Jensen, K. A., and Nygaard, B., *Acta Chem. Scand.*, **3**, 474 (1949).
[6] Calvin, M., and Barkelew, C. H., *J. Amer. Chem. Soc.*, **68**, 2267 (1946).

Some Anomalous Properties of 2′-Methoxy-2 : 4 : 4 : 7 : 4′-Pentamethylflavan

THE methylation of 2′-hydroxy-2 : 4 : 4 : 7 : 4′-pentamethylflavan (I, R=H) with dimethyl sulphate and alkali has been mentioned briefly by Baker and Besly[1], who stated that the product (I, R=Me) was obtained in an impure amorphous state and that it separated from organic solvents as a jelly.



It has now been found that this compound exhibits very unusual crystallization behaviour. It was prepared by treatment of the hydroxy-compound in acetone solution with dimethyl sulphate and 30 per cent sodium hydroxide; the crude product, isolated by evaporation of an ether extract of the reaction mixture, could readily be purified by vacuum distillation and was obtained as a clear, colourless oil, boiling point 158–167° (bath temp.)/0·02 mm., which rapidly solidified on cooling. The solid form, however, was not a normal crystalline material but a hard, very brittle and slightly opaque glass-like substance, which melted comparatively sharply at about 99–104° to give the clear liquid form. On slowly cooling the latter, it suddenly became opaque at about 93° and set to a stiff gel-like material. When the temperature had fallen to about 75°, considerable shrinkage and formation of internal fractures occurred, and the substance then assumed the hard glass-like condition which it retained down to room temperature. If the molten ether was cooled very rapidly without mechanical agitation, it was possible to obtain it in a supercooled state as a clear, highly viscous syrup, the viscosity of which increased steadily as the temperature fell. If the cooling of the molten material was not sufficiently rapid, an intermediate state could be produced in which the formation of both the opaque glass and the clear syrup had taken place simultaneously, the former assuming the shape of opaque spherical globules suspended in the transparent syrupy medium (Fig. 1; magnification 11 diameters). The syrup was only metastable, however, and after a few days reverted to the hard opaque form; this change was accelerated by warming the syrup to about 95° with slight agitation or by treating it with a solvent, such as ether.

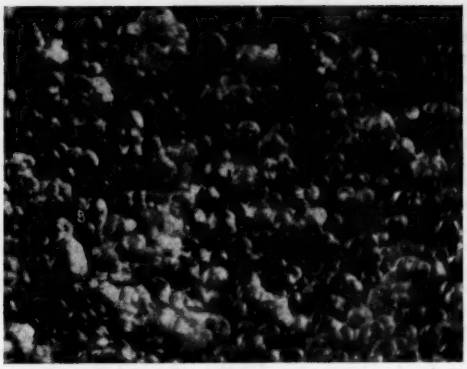


Fig. 1

The infra-red absorption spectrum of the methyl ether in the glassy state was compared with the spectra of the isomeric crystalline 2′-methoxy-2 : 4 : 4 : 6 : 5′-pentamethylflavan (II, R=Me) and of the corresponding 2′-hydroxy compounds (I, R=H and II, R=H) which are respectively a crystalline substance and an amorphous glass. The spectra of all four substances over the frequency-range 1,100–800 cm.$^{-1}$ are very similar, but a difference was found to occur in the region 820–805 cm.$^{-1}$ in that the two crystalline compounds showed here a double absorption peak, whereas the same substances in the molten state and the amorphous glass all exhibited a single peak. The methyl ether under investigation showed a single peak only, which suggests that it, too, is amorphous, although the evidence cannot be regarded as conclusive.

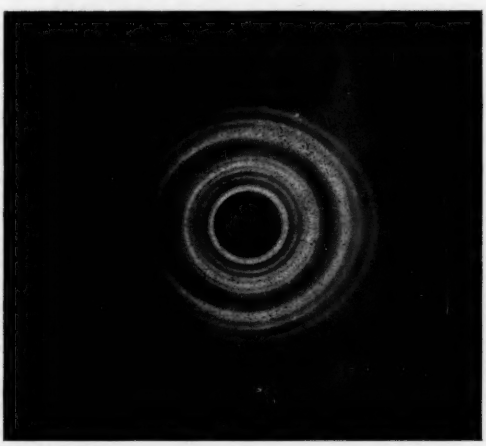


Fig. 2

An examination of the glassy form of the ether under the polarizing microscope showed it to exhibit rather weak but definite extinction; it is, in fact, not completely amorphous, but possesses at least partial orientation of the molecules and appears to be polycrystalline on a very fine scale. An X-ray powder photograph of the material led to the same conclusion, the result (Fig. 2) being similar to that given by many polymers which include both crystalline and amorphous regions.

The substance, therefore, appears to have the unusual property of crystallizing to only a limited extent; clearly it cannot be a polymer, nor is it likely to be at all highly associated, and the reason for this behaviour remains obscure at present. Further work to elucidate this is being carried out.

I wish to thank Prof. Wilson Baker for his interest, Dr. L. A. Duncanson for the infra-red measurements and Mr. C. W. Bunn and Dr. D. R. Holmes for the X-ray examination and for helpful discussions.

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The Frythe, Welwyn, Herts.
Feb. 16.

[1] Baker and Besly, *J. Chem. Soc.*, 1103 (1940).

Limits to a Firm's Control of Labour Turnover

In a recent article[1], Dr. Hilde Behrend states that her findings on labour turnover point to the conclusion that "external factors, particularly the level of employment, are the decisive factors in this field", and that this conflicts with views recently put forward by Rice, Hill and Trist[2], who are concerned with the way in which the characteristics of a particular firm may influence its turnover-rates. The difference in the interpretation of available data appears to have arisen in part through a different definition of internal and external determinants.

By the internal determinants of a system are generally meant those characteristics which define the structure and processes occurring within the system, as against the characteristics of its surrounding environment. A system is defined in terms of the elements of which it is composed, the characteristics of these elements and the relationship which exists between them. The internal determinants of a factory as a social system would, therefore, include the number of its employees, their characteristics such as sex and age, the nature of their work activities, etc., as well as the social and work relationships within the factory and its organizational structure. Dr. Behrend regards the first group of these characteristics as external, whereas Rice, Hill and Trist regard them as internal.

Dr. Behrend's conclusion that labour turnover is affected by existing employment opportunities is supported by the findings of Rice, Hill and Trist. This finding does not, however, explain variations in the rate of turnover between factories which, according to her data[3], were found to range from 13 per cent in one factory, to 112 per cent in another factory, over a period of three months.

The turnover process can be regarded as an essential aspect of an employing organization which fulfils both the needs for efficient functioning of the organization and personal needs of its employees and staff. It cannot be assumed that all firms will attempt to minimize their turnover-rates. The optimum turnover-rate will vary not only between factories but also for different types of employees within the same factory. A temporary rise in the number of persons who leave the firm may thus benefit firms who are suffering from a lag in turnover and at the same time seriously affect the efficiency of those firms the turnover-rates of which are already above the optimum. Similarly, a temporary fall in turnover-rates will be to the advantage of some firms, but not to others. The problem of labour turnover must, therefore, be considered with reference to the individual firm functioning within its environment.

P. G. Herbst

Tavistock Institute of Human Relations,
London, W.1.

[1] Behrend, H., *Nature*, **173**, 379 (1954).
[2] Rice, A. K., Hill, J. M. M., and Trist, E. L., *Human Relations*, **3**, No. 4 (1950); **4**, No. 3 (1951); **4**, No. 4 (1951); **5** No. 1 (1952); **5**, No. 4 (1952); **6**, No. 1 (1953).
[3] Behrend, H., *Occupational Psychology*, **27**, No. 2 (1953).

The question raised in my article in *Nature* of February 27 was the problem of assessing the limits of the firm's control of labour turnover. P. G. Herbst's letter, it seems to me, merely confuses the issue.

It would appear that we both agree that there are three groups of determinants of labour turnover. Briefly, we may describe these as: (1) general economic and social factors operating in the whole society; (2) differences in the behaviour of people according to their sex, age, length of service and occupation; (3) specific internal factors characteristic of a particular firm and its management.

Herbst points out that Rice, Hill and Trist consider the second group to be internal factors, while I class them as external. My reason for doing this is a simple one. The differences in the behaviour of different types of employees are not restricted to a single firm. In practically all firms, old workers have a lower turnover than young ones, men have a lower wastage-rate than women, skilled workers behave differently from unskilled ones. These differences cannot be attributed to successful management or to good human and industrial relations within the firm. Furthermore, a firm can only change the composition of its work-force in the long run, and if it does, any ensuing reduction in labour turnover would not mean that the human relations in the firm have improved.

The problem is to what extent a firm can control labour turnover through its own policy. My findings suggest that the ability of the firm to reduce labour turnover is comparatively limited, and that external factors such as the level of employment are more powerful factors and, in fact, mould managerial and personnel policies.

Rice, Hill and Trist, on the other hand, although admitting that external events cause fluctuations in the level of turnover, brush them aside as 'undulations'. For a detailed examination of their arguments with regard to this point and to the statement that labour turnover is "a function of the institution", compare Behrend, *J. Indust. Econ.*, **2**, No. 1 (1953).

Hilde Behrend

Faculty of Commerce and Social Science,
University, Birmingham 15.

FORTHCOMING EVENTS

*(Meetings marked with an asterisk * are open to the public)*

Monday, June 14

ROYAL GEOGRAPHICAL SOCIETY (at 1 Kensington Gore, London, S.W.7), at 5 p.m.—Mr. Derek J. Price: "Aspects of Medieval Survey".

Tuesday, June 15

BRITISH PSYCHOLOGICAL SOCIETY, INDUSTRIAL SECTION (in Room 105, London School of Hygiene and Tropical Medicine, Keppel Street, London, W.C.1), at 1 p.m.—Dr. N. H. Mackworth: "Field and Laboratory Studies of Cold".

UNIVERSITY OF LONDON (at the Institute of Archæology, Inner Circle, Regent's Park, London, N.W.1), at 8.15 p.m.—Dr. J. B. Griffin: "Recent Work in Archæology outside Europe". (6) "North America, South-western Prehistory".*

Wednesday, June 16

ROYAL METEOROLOGICAL SOCIETY (at 49 Cromwell Road, London, S.W.7), at 5 p.m.—Special General Meeting, followed by Scientific Papers.*

OVERSEAS SCIENCE STUDENTS' ASSOCIATION (at the Society for Visiting Scientists, 5 Old Burlington Street, London, W.1), at 7.30 p.m.—Dr. K. P. Oakley: "Techniques for Dating Bones".

Thursday, June 17

ROYAL SOCIETY (at Burlington House, Piccadilly, London, W.1) at 4.30 p.m.—Prof. A. R. Todd, F.R.S.: "Chemistry of the Nucleotides" (Bakerian Lecture).

LONDON MATHEMATICAL SOCIETY (at the Royal Astronomical Society, Burlington House, Piccadilly, London, W.1), at 5 p.m.—Prof. P. Hall: "Free Groups and Symmetric Functions".

ROYAL SOCIETY OF TROPICAL MEDICINE AND HYGIENE (at Manson House, 26 Portland Place, London, W.1), at 7.30 p.m.—Annual General Meeting. Dr. C. C. Chesterman, O.B.E.: "The Training and Employment of African Auxiliary Medical Personnel".

Thursday, June 17—Friday, June 18

ASLIB, NORTHERN BRANCH (at the Falcon Hotel, Saltergate, Lincoln)—Conference.

Friday, June 18

INSTITUTE OF NAVIGATION (at the Royal Geographical Society, 1 Kensington Gore, London, S.W.7), at 5 p.m.—Discussion on "Methods of Training in Navigation", introduced by Mr. W. L. S. Harrison.

ROYAL INSTITUTION (at 21 Albemarle Street, London, W.1), at 9 p.m.—Mr. G. Mackworth-Young: "What Happens in Singing".

Saturday, June 19

BIOCHEMICAL SOCIETY (in the Department of Biochemistry, The University, Cambridge), at 11 a.m.—Scientific Papers.

APPOINTMENTS VACANT

APPLICATIONS are invited for the following appointments on or before the dates mentioned:

ASSISTANT LECTURER IN APPLIED MATHEMATICS—The Registrar, The University, Hull (June 18).

ASSISTANT LECTURER (with a good honours degree) IN PHYSICS—The Registrar, King's College, Strand, London, W.C.2 (June 18).

LECTURER IN PATHOLOGY at the Royal Infirmary, Glasgow—The Secretary of University Court, The University, Glasgow (June 18).

LECTURER or ASSISTANT (Grade B) IN ZOOLOGY, a SENIOR LECTURER, LECTURER or ASSISTANT (Grade B), IN THE DEPARTMENT OF PHYSIOLOGY—The Clerk to the Governors, Chelsea Polytechnic, Manresa Road, London, S.W.3 (June 18).

ASSISTANT LECTURER (with a good honours degree in physics, and preferably with research and/or industrial and teaching experience) IN PHYSICS, and a GRADUATE (preferably with industrial and/or research experience) to teach two of the subjects of physics, chemistry and mathematics, chiefly to the standard of ordinary national certificate, at the Technical College of Monmouthshire, Crumlin—The Director of Education, County Hall, Newport, Mon. (June 19).

GEORGE ANGUS STUDENT (graduate of an approved university or holder of approved qualifications) for postgraduate research in the Department of either Chemistry, Physics or Mechanical Engineering—The Registrar, King's College, Newcastle-upon-Tyne (June 19).

LECTURER (preferably with practical experience and a special interest in surveying) IN CIVIL ENGINEERING—The Secretary, Queen's University, Belfast (June 19).

LECTURER, and an ASSISTANT LECTURER, IN BACTERIOLOGY—The Registrar, Trinity College, Dublin (June 19).

LECTURER (with an honours degree in botany or agricultural botany, and preferably with a knowledge of zoology and experience of teaching) IN BOTANY—The Secretary, Edinburgh and East of Scotland College of Agriculture, 13 George Square, Edinburgh (June 19).

RESEARCH ASSISTANT (science graduate of a British university or Associate Member of the Institute of Medical Laboratory Technology) to work on the blood group serology of neoplastic disease, under the supervision of the Honorary Director of Cancer Research, Sheffield University—The Registrar, The University, Sheffield (June 19).

SENIOR LECTURER (with qualifications and experience necessary to plan and supervise the teaching of organic chemistry up to honours degree standard) IN ORGANIC CHEMISTRY—The Principal, Royal Technical College, Salford (June 19).

ASSISTANT ANALYST (with either a university degree or the A.R.I.C., and preferably with experience in the analysis of food and drugs)—The County Medical Officer of Health, East Cliff County Offices, Preston, quoting "Assistant Analyst" (June 21).

LECTURER or ASSISTANT LECTURER (graduate in chemical engineering or chemistry, with postgraduate training and/or experience in chemical engineering) IN CHEMICAL ENGINEERING—The Registrar, College of Technology, Manchester 1 (June 21).

ASSISTANT LECTURERS (2) IN THE DEPARTMENT OF GEOLOGY—The Secretary and Registrar, The University, Southampton (June 22).

ASSISTANT (with at least H.S.C. or equivalent with chemistry and physics) AT THE NATURE CONSERVANCY BIOLOGICAL RESEARCH STATION, Grange-over-Sands, for work on soils as part of a research programme on moorlands, with occasional field work at Moor House Field Station, Westmorland—The Establishment Officer, The Nature Conservancy, 19 Belgrave Square, London, S.W.1 (June 22).

LECTURER or ASSISTANT LECTURER (with a special interest in endocrinology and pharmacology) IN PHYSIOLOGY—The Secretary, Royal Veterinary College and Hospital, Royal College Street, London, N.W.1 (June 23).

ASSISTANT LECTURER IN ZOOLOGY—The Registrar, University College, Leicester (June 25).

READER IN CHEMICAL ENGINEERING at the Imperial College of Science and Technology—The Academic Registrar, University of London, Senate House, W.C.1 (June 28).

SCIENTIFIC TECHNICAL OFFICERS, Grade II (preferably with higher national certificate or a degree in physics or equivalent qualifications in electronics, radio engineering or a higher national certificate or a degree in mechanical subjects)—The National Coal Board Central Research Establishment, Stoke Orchard, near Cheltenham, Glos, quoting T7/786 (June 28).

ASSISTANT LECTURER (preferably with a knowledge of electrophysiology) IN PHYSIOLOGY—The Registrar, University College of South Wales and Monmouthshire, Cathays Park, Cardiff (June 30).

LECTURER IN BIOCHEMISTRY, LECTURER/SENIOR LECTURER IN AGRICULTURE, LECTURER IN MECHANICAL ENGINEERING, and a SENIOR LECTURER IN SOIL SCIENCE, at the University of Sydney, Australia—The Secretary, Association of Universities of the British Commonwealth, 5 Gordon Square, London, W.C.1 (June 30).

LECTURER IN ZOOLOGY at the University College of the Gold Coast—The Secretary, Inter-University Council for Higher Education in the Colonies, 1 Gordon Square, London, W.C.1 (June 30).

LECTURER (with an interest in the physico-chemical aspects of life processes in plant and animal material) IN THE DEPARTMENT OF NATURAL PHILOSOPHY, BIOPHYSICS UNIT—The Secretary, The University, Edinburgh (June 30).

PROFESSOR OF GEOLOGY at the University of Saugar, Sagar, M.P., India—The Secretary, Association of Universities of the British Commonwealth, 5 Gordon Square, London, W.C.1 (June 30).

RESEARCH ASSISTANTS (with an honours degree of a British university or equivalent qualification) IN MATHEMATICAL ENGINEERING, ELECTRICAL ENGINEERING, APPLIED CHEMISTRY, APPLIED BIOCHEMISTRY, APPLIED PHYSICS, and MINING—The Principal, Heriot-Watt College, Edinburgh (June 30).

DEMONSTRATOR IN THE DEPARTMENT OF BOTANY—The Registrar, The University, Leeds 2 (July 1).

SENIOR LECTURER IN TOWN PLANNING at Auckland University College (University of New Zealand)—The Secretary, Association of Universities of the British Commonwealth, 5 Gordon Square, London, W.C.1 (New Zealand, July 31).

ASSISTANT, Grade B (with a good degree in physics of a British university, and preferably with industrial and/or research experience) IN PHYSICS—The Principal, Medway College of Technology, Horsted, Maidstone Road, Chatham, Kent.

ASSISTANT INFORMATION OFFICER (with a scientific background, and ability to work without supervision, and to co-operate with others) to work in the Sheffield laboratories of the British Iron and Steel Research Association, and be responsible for a branch library and information service, obtaining technical publications, and supplying information about the work of the Association—The Personnel Officer, B.I.S.R.A., 11 Park Lane, London, W.1.

BIOCHEMICAL TECHNICIAN (with the Institute of Medical Laboratory Technology Diploma in Chemical Pathology, or a degree in chemistry, or equivalent qualification) IN THE DEPARTMENT OF PATHOLOGY—The Hospital Secretary, Canadian Red Cross Memorial Hospital, Taplow, near Maidenhead.

BIOCHEMIST (with a first- or second-class honours degree in biochemistry or chemistry, or equivalent qualifications), for research on fat metabolism, with particular reference to the depot fats of ruminants—The Secretary, Rowett Research Institute, Bucksburn, Aberdeenshire.

LECTURER IN CHEMISTRY, and a LECTURER (with a good honours degree in electrical engineering and some experience in servo mechanisms) IN ELECTRONICS—The Secretary, Royal Technical College, Glasgow.

LECTURER or ASSISTANT PROFESSOR (preferably with industrial experience) IN CHEMICAL ENGINEERING, to give unit operations course with laboratory and design calculations course to junior and senior year classes—Nova Scotia Technical College, P.O. Box 1000, Halifax, Nova Scotia.

LECTURER (with a good honours degree in engineering, and practical training and/or research experience) IN MECHANICAL ENGINEERING—The Registrar, The University, Nottingham.

PRINCIPAL SCIENTIFIC OFFICER (Geophysicist) (with a good honours degree in physics or geology, and several years practical experience of seismic and gravitational prospecting and general knowledge of other methods of geophysical prospecting) (Ref. A.133/54A); and a SENIOR SCIENTIFIC OFFICER (Geophysicist) (with a good honours degree in geology, with postgraduate study in geophysics and with some field experience in geophysical prospecting) (Ref. G.161/54A),

with the Directorate of Colonial Geological Surveys, for duties initially at London Headquarters, and later a considerable period in Colonial territories—The Ministry of Labour and National Service, Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting appropriate Ref. No.

Scientific Officers (with a first- or second-class honours degree or equivalent in physics, mathematics or engineering, and preferably with a taste for broad assessment work leading to selection of aircraft and other equipment for military and civilian use) at the London Headquarters of the Ministry of Supply, for work with a project assessment group—The Ministry of Labour and National Service, Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A.135/54A.

Technician (Assist Steward) (with previous experience in chemical or biological laboratory practice) in the Department of Zoology—The Registrar, The University, Nottingham.

Wool Textile Research Council Fellow (with university degree or equivalent technological qualifications) for research on woollen yarn manufacture—The Principal, Technical College, Queen Street South, Huddersfield.

REPORTS and other PUBLICATIONS

(not included in the monthly Books Supplement

Great Britain and Ireland

The Story of Cobalt Deficiency in Animal Health. By C. S. M. Hopkirk and J. B. E. Patterson. Pp. 26. (London: The Mond Nickel Company, Ltd., 1954.) [74

Ministry of Agriculture and Fisheries: Department of Agriculture for Scotland. Report of the Advisory Committee on Myxomatosis. Pp. iv+14. (London: H.M. Stationery Office, 1954.) 9*d*. net. [134

Projection Welding of Mild Steel. (T.30.) Pp. ii+14. (London: British Welding Research Association, 1954.) 3*s*. 6*d*. [134

Department of Scientific and Industrial Research. Road Research Technical Paper No. 30: A Study of Single-sized Gravel Aggregates for Roadmaking. By F. A. Shergold. Pp. iv+20. (London: H.M. Stationery Office, 1954.) 1*s*. net. [134

City and Guilds of London Institute. Annual Report of the Council, 1st January to 30th September, 1953. Pp. 47+xiii. (London: City and Guilds of London Institute, 1954.) [134

Ministry of Fuel and Power. Report of H.M. Inspectors of Mines, under the Coal Mines Act, 1911, for the year 1952. Northern Division. By W. Brown. Pp. ii+34. (London: H.M. Stationery Office, 1954.) 1*s*. 6*d*. net. [134

Mushroom Science II: the Proceedings of the Second International Conference on Scientific Aspects of Mushroom Growing, Gembloux, 1953. Pp. 184. (Yaxley, Peterborough: Mushroom Growers Association, 1954.) 12*s*. [134

The Classic and Romantic in Natural Philosophy. By Prof. G. Temple. (An Inaugural Lecture delivered before the University of Oxford on 2 March 1954.) Pp. 22. (Oxford: Clarendon Press; London: Oxford University Press, 1954.) 2*s*. 6*d*. net. [134

Department of Scientific and Industrial Research. Report of the Water Pollution Research Board, with the Report of the Director of Water Pollution Research, for the year 1953. Pp. iv+62+4 plates. (London: H.M. Stationery Office, 1954.) 2*s*. 6*d*. net. [134

National Research Development Corporation. Bulletin No. 1, April 1954. (A quarterly review of inventions available for introduction to industry.) Pp. 20. (London: National Research Development Corporation, 1954.) [134

Proceedings of the British Weed Control Conference, November 3rd, 4th and 5th, 1953. Margate, England. Pp. viii+484. (London: Association of British Insecticide Manufacturers, 86 Strand, 1954.) 30*s*. [134

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